Historical Cropping Practices in Eastern South Dakota and their Effect on Sediment and Nutrient Transport

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HISTORICAL CROPPING PRACTICES IN EASTERN SOUTH DAKOTA AND THEIR EFFECT ON SEDIMENT AND NUTRIENT TRANSPORT

BY

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AND THEIR EFFECT ON SEDIMENT AND NUTRIENT TRANSPORT

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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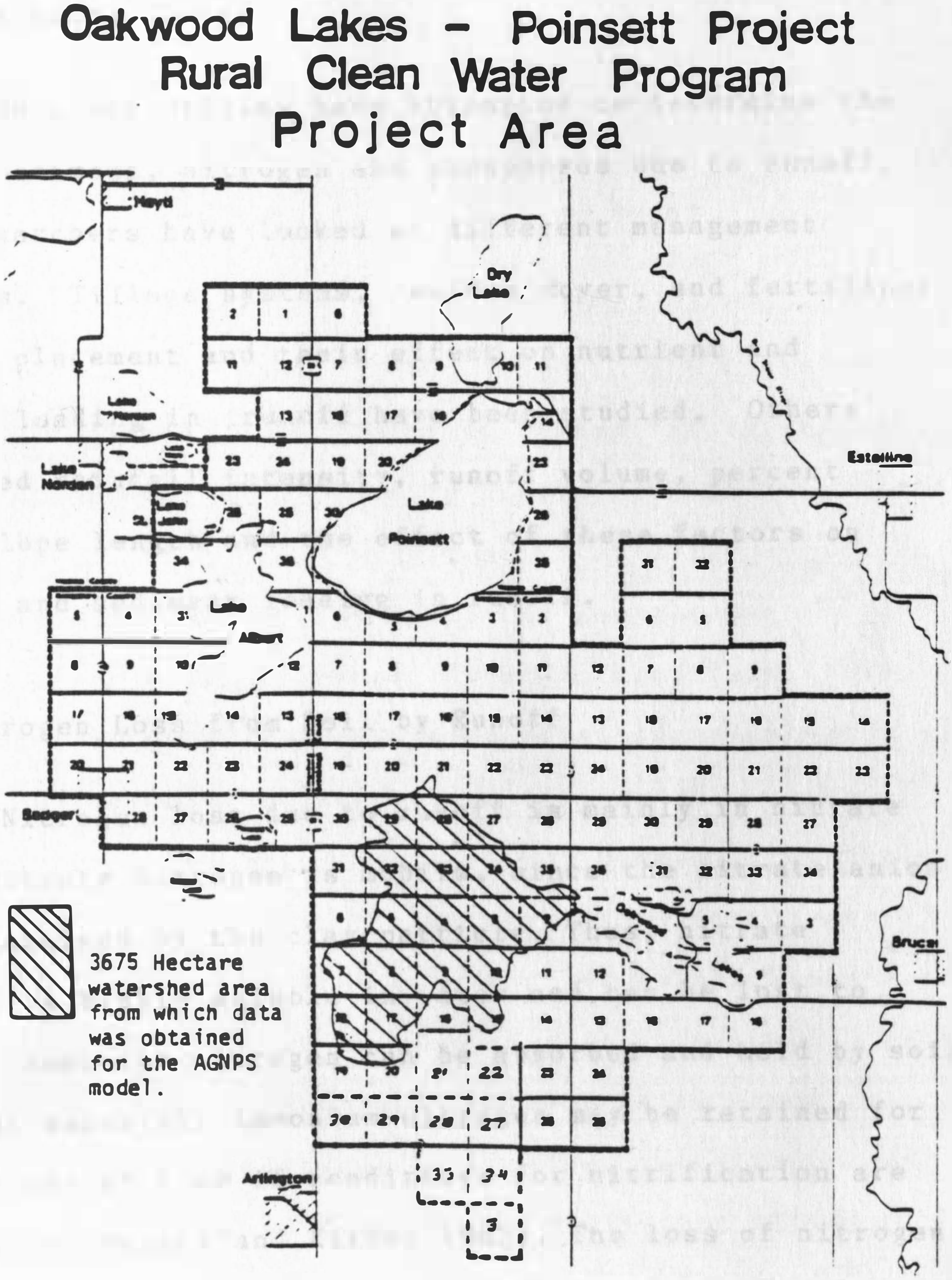
I. Introduction

Increased fertilizer and pesticide usage and their effects on our lakes and streams are two of the intense farming practices that the public is becoming increasingly concerned about. When the nutrient and mineral concentrations of our lakes and streams become extreme the water may become unsuitable for human consumption and undesirable for recreational use. It is possible that the nutrient loading of lakes and streams is due to an increase of fertilizer applications. Nitrogen and phosphorus are the main elements considered. Some of the increased nutrient concentration in our lakes and streams is agriculturally related. Which practices conducted by farmers contribute the largest concentrations and which practices will reduce nutrient and sediment transport?

To predict the effect of different management practices, a number of models have been built to simulate a runoff event. Runoff events are complex to model because there are a large number of factors to consider. Some of these factors are soil type, storm intensity, slope, tillage practices, and ground cover. A model can help determine the effect of a management practice before it is implemented and therefore help to make a beneficial management decision.

The objectives of this study were: (1) To determine the historical tillage, historical fertilization, historical crops planted, and historical livestock populations in the Oakwood Lakes - Poinsett Project Area (Figure 1). (2) Use the Agricultural Nonpoint Source Pollution Model (Young et al. 1985) to determine the effect of historical cropping practices on the transport of sediment, nitrogen, and phosphorus within a 3675 hectare watershed in the Oakwood Lakes-Poinsett Project Area.



Oakwood Lakes - Poinsett Project
Rural Clean Water Program
Project Area
Hayti
Dry Lake
Lake Norden
Lake Poinsett
Estelline
Badger
Arlington
3675 Hectare watershed area from which data was obtained for the AGNPS model.

Figure 1.

II. Literature Review

Numerous studies have attempted to determine the loss of sediment, nitrogen and phosphorus due to runoff. Some researchers have looked at different management practices. Tillage systems, residue cover, and fertilizer rate and placement and their effect on nutrient and sediment loading in runoff have been studied. Others considered rainfall intensity, runoff volume, percent slope, slope length and the effect of these factors on nutrient and sediment loading in runoff.

1. Nitrogen Loss from Soil by Runoff

Nitrogen loss due to runoff is mainly in nitrate form. Nitrate nitrogen is mobile, since the nitrate anion is not retained by the clay particle. Thus, nitrate nitrogen is highly soluble in water and can be lost to runoff. Ammonium nitrogen can be absorbed and held by soil colloidal material. Ammonium nitrogen may be retained for long periods of time if conditions for nitrification are unfavorable (Mengel and Kirkby 1982). The loss of nitrogen in this form is primarily due to soil erosion. The loss of nitrogen is affected by a number of factors. Rate of application, timing of application and surface cover are just some of the factors that affect surface transport of nitrogen.

1.1 Effect of Nitrogen Application rates on the Loss of Nitrogen to Runoff

The application of fertilizer nitrogen has steadily increased during the past three decades. This increase in use has been pointed at as being the cause for increased nitrate concentrations in surface water. The nitrate ion is very active, thus the longer fertilizer nitrogen remains unused, the greater the probability of loss by one mechanism or another. Klausner, Zwerman, and Ellis (1974) stated that excessive fertilization or application prior to wet seasons increase the susceptibility toward nutrient losses by surface runoff. In the study done by Klausner, Zeverman and Ellis (1974), it was shown that discharges of ammonium nitrogen in surface runoff on an annual basis were not significantly related to crop, fertility or soil management practices. However, the nitrate nitrogen discharges were directly related to crop, fertilizer, and soil management. The highest losses of nitrate nitrogen occurred when heavy fall fertilization was practiced. Thus, fall fertilization should be avoided. Baker and Laflen's (1982) results showed that concentrations of nitrate nitrogen in the water were slightly increased by fertilization, but losses of ammonium nitrogen were significantly increased by fertilization. The reason for the difference in behavior is that the ammonium nitrogen will interact strongly with the soil and remain at the place of application while nitrate nitrogen is not absorbed and will move down readily in the soil profile with the water. Thus, the ammonium nitrogen is more susceptible to runoff than nitrate nitrogen. When conditions are less conducive to initial infiltration, the mobile nitrate nitrogen may not be leached from the surface. Thus, nitrate would be susceptible to runoff loss (Baker and Laflen 1982). A study done by Kohl, Shearer and Commer (1971) concluded that fertilizer nitrogen contributed 55 percent + or - 10 percent of the nitrates entering Lake Decautes (study area).

1.2 Effect of Tillage and Nitrogen Application on the Loss of Nitrogen by Runoff.

Losses of nitrogen by erosion are probably more serious than losses of any other nutrient. Nitrate nitrogen can be easily lost to runoff, while ammonium nitrogen lost to soil erosion. Soil cover, method of incorporating fertilizer and the timing of fertilizer applications all have an affect on nitrogen loss with the sediment load of runoff water. Baker and Laflen (1982) showed a decrease in flow - weighted concentration of ammonium nitrogen in the runoff from fertilized plots by increasing the surface residue. The residue caused an increase in the time before surface runoff began, which allowed the nitrate nitrogen to leach down. Overall, they found an 80 percent decrease in nutrient loss from plots with the greatest residue amount. Veits (1968) studied the affect conservation tillage has on sediment and nutrient loss. He compared conservation tillage to conventional tillage under corn, soybeans, wheat, and meadow. He found nitrogen and sediment losses were less under conservation tillage than under conventional tillage. In a study done by Johnson et al. (1979), two conservation tillage systems were compared to a conventional tillage system. They found conservation tillage reduced runoff by about 40 percent and reduced soil loss from 60 to 90 percent. Thus, total losses of nitrogen, which was mostly associated with soil loss, decreased for conservation tillage.

Another factor which affects the amount of nitrogen loss due to runoff is the placement of fertilizer nitrogen. Baker and Laflen (1982) studied the effect fertilizer placement has on nutrient loss. They found that surface fertilization significantly increased ammonium nitrogen concentrations in runoff. Losses of nutrients from plots where fertilizer was injected five centimeters in the soil were no different from losses where no fertilizer was applied (Baker and Laflen 1982). Baker and Laflen (1982) found that placement of nutrient below the residue and on top of the soil did not significantly decrease runoff losses. Moe, Mannering and Johnson (1967) indicated that 50 percent of the nitrogen applied to the surface of either sod or fallow was lost to runoff after a 5.0 inches rain.

A factor that is important in reducing nutrient loss is timing of application. Klausner, Zwerman and Ellis (1974) believed that the time of nitrogen fertilization is important from a nutrient availability standpoint and excessive fertilization or application prior to a wet season increases the susceptibility of losses by surface runoff. They concluded heavy fall fertilization should not be practiced. By fertilizing with split nitrogen applications, there is a minimum opportunity for the loss of nitrogen. A split application also resulted in yield increases and higher recovery of nitrogen (Jung, Peterson, and Schroder 1972; Olson, Lanke and Rhoads 1960; Rehm and Wiese 1975).

1.3 Environmental Factors Affecting the Loss of Nitrogen by Runoff

Some of the environmental factors that may increase or decrease the loss of nitrogen to runoff are rainfall intensity, rainfall duration, rainfall frequency, soil structure, soil type and drainage capability. These factors are known to affect the surface runoff. White (1983) studied the relative importance of antecedent moisture content, event precipitation amount, high intensity precipitation, runoff volume, minimum and average concentration of nutrients in the precipitation, and minimum and average content of nutrients in the runoff. He found that the runoff volume was the most important factor in determining nitrate nitrogen loss. Ammonium nitrogen loss was more dependent on content in the precipitation. Moe, Mannering, and Johnson (1967) found that the moisture content of the soil in a plot at the time of nitrogen fertilizer application had a greater effect on the amount of mineral nitrogen loss than on the amount of total runoff. Initially wet plots lost ten times as much nitrogen as did the drier plots during the first 2.5 inch storm. Taylor et al. (1971) concluded that losses are closely related to the volume of runoff. Viets (1968) concluded that losses depend mainly on the amount of soil erosion, which is the greatest carrier of nitrogen to the waterways. In a study done by Moe et al. (1967,1968), they applied 60 pounds of nitrogen to sod and to sealed and open fallow plots. The soil was a silt loam on a 13 percent slope.

The soil had a fragipan at 2 to 3 feet. They applied 5 inches of rain in 24 hours. They found a loss of 3.1 percent of the applied mineral nitrogen on the fallow plots having the open surface and 8.29 percent of the applied mineral nitrogen was lost on a fallow plot having the sealed surface. The amount of organic nitrogen lost from fallow plots (28 to 62 pounds per acre) exceeded the amount of mineral nitrogen lost from the same plots (6 to 16 pounds per acre). However, the fallow plots lost larger amounts of soil sediment than did the sod plots. The total nitrogen loss (mineral nitrogen plus organic nitrogen) was greater from fallow plots than from sod plots.

2. Phosphorus Loss from Soil by Runoff.

Under normal field conditions phosphorus is one of the least mobile plant nutrients. From .02 to .15 percent of the phosphorus in the soil is orthophosphate (Mengel and Kirkby 1982). Most of the total phosphorus is associated with organic matter. In a mineral soil 20 to 80% of the total phosphorus is organic phosphorus (Mengel and Kirkby 1983). The percent of organic phosphorus is largely dependent on the age of the soil. Phosphorus held on clay surfaces may represent up to fifty percent of the total phosphorus. Since phosphorus is not very mobile, when it is applied as an amendment on the surface, it becomes very susceptible to losses by the transport either as a clay sized mineral or with organic matter. The rate of application, timing of application, environmental factors and tillage practices are just some of the things that will affect the loss of phosphorus with runoff.

2.1 Effect of Phosphorus Application Rates on Loss of Phosphorus to Runoff.

With the present increase in the use of phosphorus fertilizer, one can only assume that additional amounts of phosphorus may eventually find their way into the surface water, especially, if it remains at or near the soil surface (Holt, Timmone, and Latterell 1970). Weibel et al. (1966) reported a greater amount of phosphorus in runoff from an "improved" farming system which had higher fertility levels. Klausner, Zwerman and Ellis (1974) showed inorganic phosphorus losses were directly influenced by fertility level and soil management practices. When a high level of phosphorus was applied to soil that had no protection, three times as much phosphorus was lost as when the fertilizer was applied and residue was left on the surface. White (1983) found soluble and total phosphate phosphorus concentration in the runoff paralleled the end of the season phosphorus content for treatments at three fertilizer rates (60, 90, and 120 pounds of phosphorus per acre). Baker and Laflen (1982) found the losses of phosphate phosphorus were significantly increased by surface applied phosphorus by a factor of 4 to 7. When phosphorus was injected 5 centimeters, there was no difference in loss between fertilized and unfertilized plots.

2.2 Effect of Tillage and Fertilizer Application on the Loss of Phosphorus by Runoff

High losses of phosphorus by erosion have been reported by a number of investigators. Soil cover, method of incorporation, and timing of application have an affect on the amount of phosphorus loss to erosion. Johnson et al. (1979) determined the quantitative relationship of water, soil, and nutrient losses among three tillage systems (conventional plowing and planting, till planting, and ridge planting). They measured soluble phosphate phosphorus lost with runoff water and total phosphorus lost with sediment. They found 80 to 99 percent of the losses for each treatment were associated with sediment. Conservation tillage systems reduced phosphorus losses because of the reduced soil losses. When they only considered available phosphorus, concentrations in the runoff were higher for conservation tillage systems than for conventional tillage. They believed this was due to the lack of phosphorus incorporation with reduced tillage and to phosphate phosphorus released from degrading residue. Timmons et al. (1973) showed that nutrient concentrations in runoff are related to the degree of fertilization. They found that incorporation of surface applied fertilizers by moldboard plowing reduced runoff losses of phosphorus to the levels of losses from unfertilized plots. Baker and Laflen (1982) found increased nutrient concentration in runoff under conservation tillage systems due in some part to the lack of fertilizer incorporation. They also found point injection of fertilizer to a depth of five centimeters a feasible method of incorporation. Losses where fertilizers were injected were no different from plots where no fertilizers were applied. Baker and Laflen (1982) found no statistically significant water quality advantage by placement of phosphorus above or below residue.

3. Sediment Loss to Runoff

Greer (1971) found if soil was unprotected during planting, excessive-rate storms would yield 50 percent of the total soil lost in one year, while during this unprotected period the storms accounted for only 6 percent of the total rainfall. If the soil was protected with 70 to 100 percent cover only 25 percent of the total soil was lost. Ground cover and canopy cover are very important in controlling erosion. The loss of sediment during a growing season occurs primarily during seedbed preparations. Laflen et al. (1978) studied six tillage practices (conventional, till-plant, disk, chisel, ridge and fluted coulter) which were performed parallel with the rows, which ran up and down hills. For the three soils they worked, they found that increased residue cover resulted in a lower erosion rate. Sediment concentrations in the runoff were higher under conventional tillage in all treatments but one. The exception was ridge till treatment on a steep slope. Using an up and down hill farming program, the ridge till system did not stop erosion. Swanson and Currence (1971) compared three tillage systems for their effect on soil and water loss. Soil losses were the greatest under conventional tillage. Till-planting had lesser amounts of soil loss. Ridge till proved to be the best system for reducing soil loss. In 1979 (Johnson et al.) compared sediment loss with continuous plowing, till planting and ridge-planting. They found ridge tillage and till planting reduced runoff 40 percent and reduced soil loss from 60 to 90 percent with no difference in yield compared to conventional tillage.

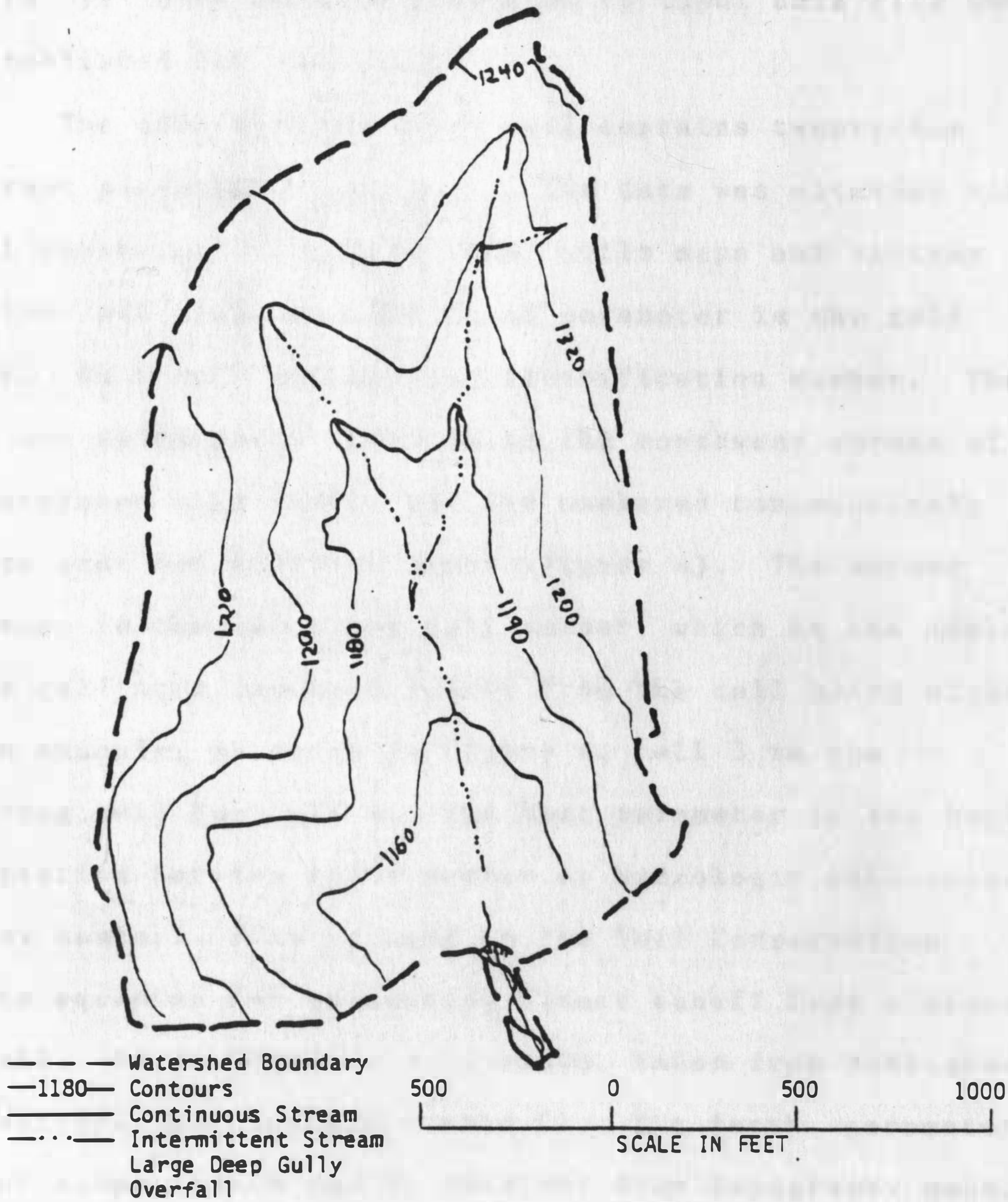
III. Materials and Methods

The work reported on in this paper relates to a portion of the Oakwood Lakes - Poinsett Rural Clean Water Program Project area (figure 1). The modeled watershed was a fan shaped area of 3675 hectares (9080 acres) which drains into the west edge of Lake Tetonkaha, the western lake of Oakwood Lakes, (figure 1). The Agricultural Nonpoint Source Pollution Model used in this paper was developed by the United States Department of Agriculture and Agricultural Research Service in cooperation with the Minnesota Pollution Control Agency, the Minnesota Soil and Water Conservation Board, Soil Conservation Service, and Minnesota Land Management Information Service. The model was run on a Hewlett Packard 1000 computer system located at an Agricultural Research Service Facility in Morris, Minnesota.

1. Description of the Model

The Agriculture Nonpoint Source Pollution Model is a single rainfall event based model which works on a cell basis. To develop the data set for the execution of this model one needs to follow certain steps. The first step in development is to obtain a detailed topography map and draw out the drainage boundary of the watershed (figure 2). Then

Figure 2. The example watershed with drainage patterns.



the watershed needs to be broken down into constant sized cells and determine the drainage patterns from the cells (figure 3). Once this is completed an input data file can be established for each cell.

The data file for each cell contains twenty-one different parameters (table 1). The data was obtained via visual analysis, topography maps, soils maps and various technical publications. The first parameter is the cell number. Each cell contains an identification number. The cells are numbered by starting in the northwest corner of the watershed with number one and numbered consecutively west to east and north to south (figure 4). The second parameter is the receiving cell number, which is the number of the cell that receives runoff from the cell being worked on. An example, as shown in figure 4, cell 3 is the receiving cell for cell 1. The next parameter is the Soil Conservation Service curve number or hydrologic soil-cover complex number. This is used in the Soil Conservation Service equation for estimating direct runoff from a storm rainfall. It is based on soil group, taken from published soil surveys, and landuse (table 2). The forth parameter is land slope, which can be obtained from topography maps. The fifth parameter is the slope shape factor, which is an identification number used to determine the slope shape in the cell. A number one indicates a uniform slope, number

Figure 3.The example watershed with forty acre cells and drainage pattern.

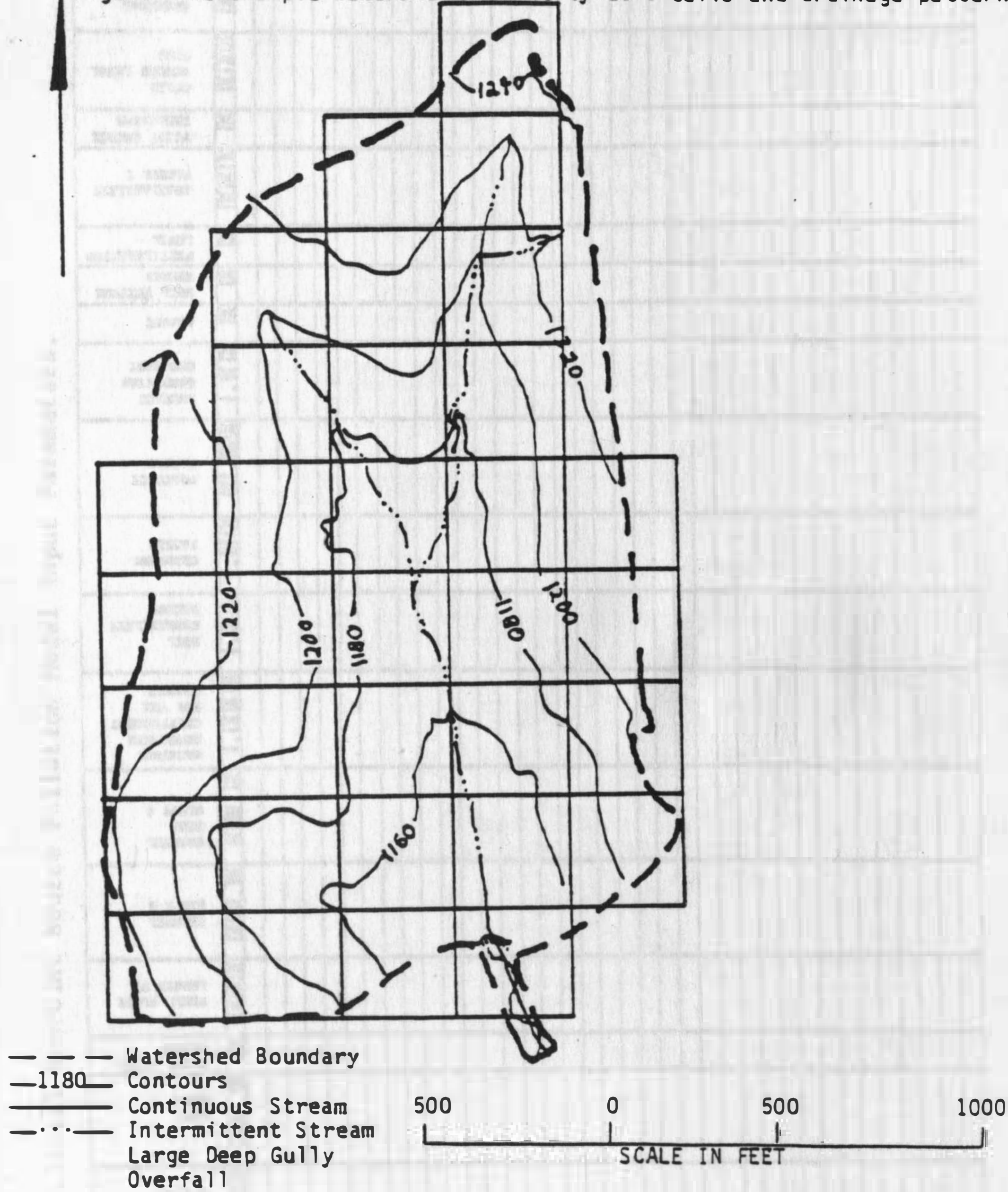


Table 1. Agricultural NonPoint Source Pollution Model Input Parameters.

CELL NUMBER	RECEIVING CELL NUMBER	SCS CURVE NUMBER	LAND SLOPE %	SLOPE SHAPE FACTOR	FIELD SLOPE LENGTH FT.	CHANNEL SLOPE %	CHANNEL SIDE SLOPE %	MANNINGS ROUGHNESS COEFFICIENT FOR THE CHANNEL	SOIL ERODIBILITY FACTOR	CROPPING FACTOR	PRACTICE FACTOR	SURFACE CONDITION CONSTANT	ASPECT	SOIL TEXTURE NUMBER	FERTILIZATION LEVEL	AVAILABILITY FACTOR %	POINT SOURCE INDICATOR	GULLY SOURCE LEVEL TONS	CHEMICAL OXYGEN DEMAND FACTOR	IMPOUNDMENT FACTOR
XXX	XXX	XXX	XX.X	X	XXX	XX.X	XX.X	.XXX	.XX	.XX	X.XX	.XX	X	X	X	XXX	X	XXX	XXX	XX

Figure 4. The example watershed with the cells and drainage patterns.

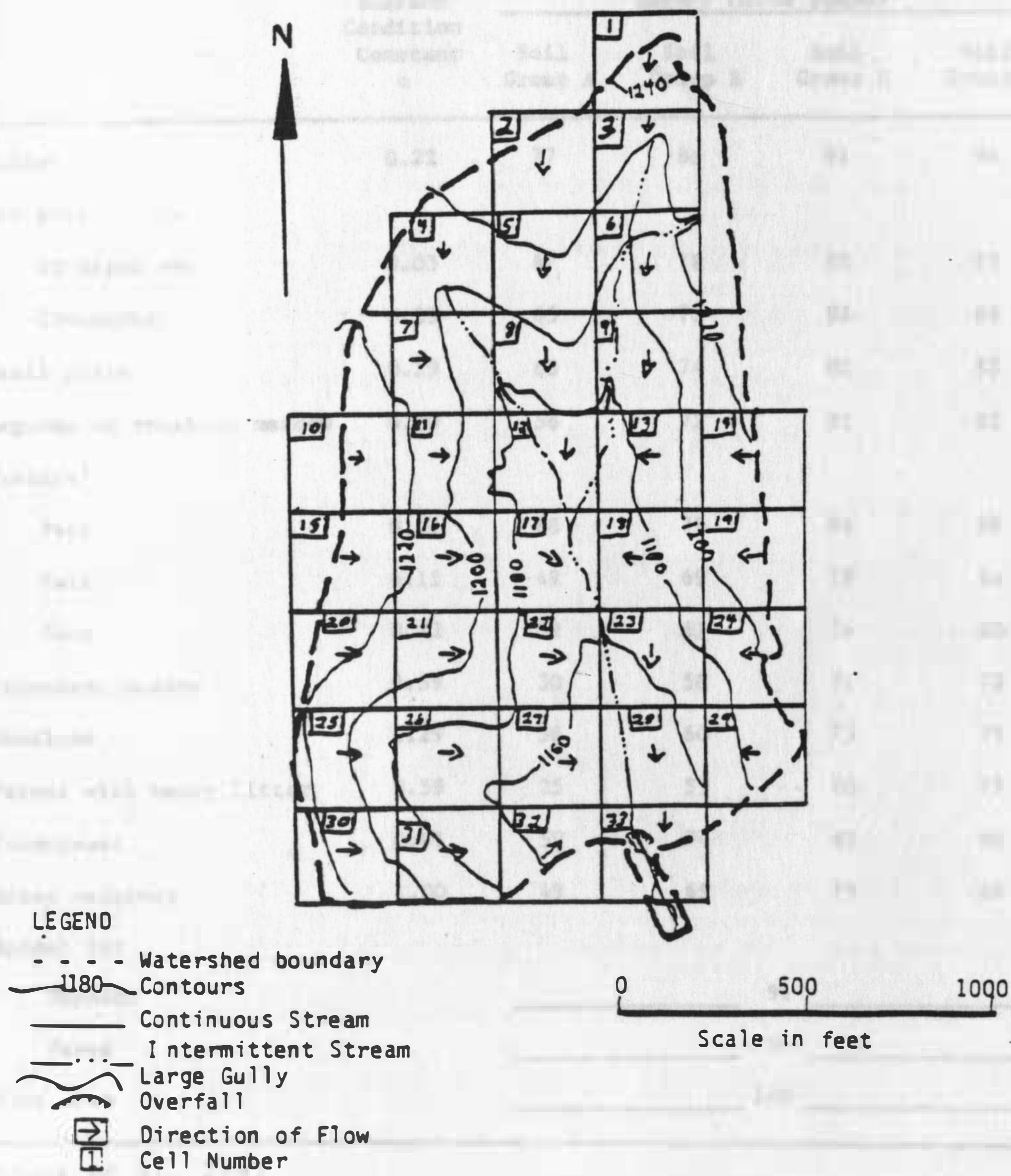


Table 2. **Runoff curve numbers and surface condition constants for various land use situations.**

	Surface[2] Condition Constant c	Runoff Curve Number[3] Soil Group A	Soil Group B	Soil Group C	Soil Group D
Fallow	0.22	77	86	91	94
Row crop					
Straight row	0.05	67	78	85	89
Contoured	0.29	65	75	82	86
Small grain	0.29	63	74	82	85
Legumes or rotation meadow	0.29	58	72	81	85
Pasture[1]					
Poor	0.01	68	79	86	89
Fair	0.15	49	69	79	84
Good	0.22	39	61	74	80
Permanent meadow	0.59	30	58	71	78
Woodland	0.29	36	60	73	79
Forest with heavy litter	0.59	25	55	70	77
Farmsteads	0.01	59	74	82	86
Grass waterway	1.00	49	69	79	84
Animal lot					
Unpaved			91		
Paved			94		
Roof area			100		

Young et al. 1985

two indicates a convex slope and number three indicates a concave slope is present in the cell (figure 5). The sixth parameter is the field slope length. It is based on the percent land slope and major field slope length area (table 3). The watershed is located in slope length area two. The seventh parameter is channel slope and can be obtained from a topography map or a field measurement. When there is no definable channel, the channel slope is assumed to be one half of the land slope. The eighth parameter is channel side slope which can be obtained by an actual measurement. If the side slope can not be measured, assume the slope is 5 percent. The ninth value is the mannings roughness coefficient for the channel. The mannings roughness coefficient values are dependent upon the amount of cover or material in the channel (table 4). The tenth parameter is the soil erodibility factor. This factor (K) is used in the universal soil loss equation and is dependent on soil type, which can be obtained from Soil Conservation Service technical guide (Soil Conservation Service). The eleventh parameter is the cropping factor which is used in the universal soil loss equation. The cropping factor is based on the amount of residue left on the surface after certain management practices. The variables involved in determining the cropping factor are previous years and current years crop, previous years and current years yield, current years

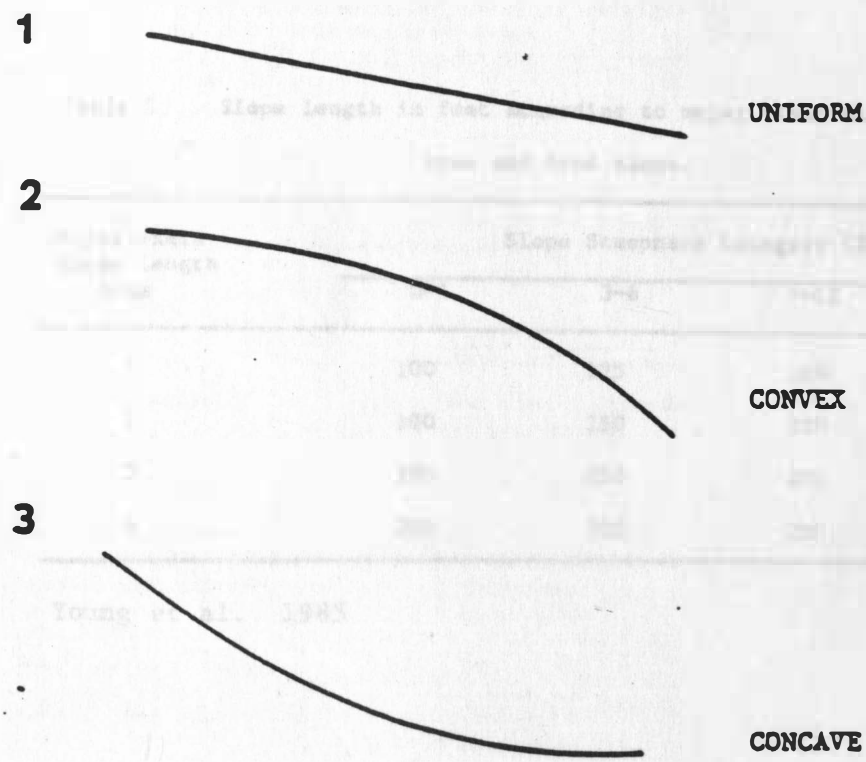


Figure 5. Examples of various slope shapes and the identification numbers given to each.
Young, et al. 1985

Table 3. Slope length in feet according to major field slope length area and land slope.

Major Field Slope Length Area	Slope Steepness Category (%)			
	0-2	3-6	7-12	≥ 13
1	100	125	100	75
2	100	250	200	150
3	200	250	200	150
4	200	200	200	200

Young et al. 1985

Table 4 . Mannings roughness coefficients for channelized flow.

NATURAL CHANNELS[1]

Description	n
Excavated or dredged channels	
Earth, straight, uniform, and clean	0.022
Same, but with some short grass or weeds	0.027
Earth, winding and sluggish, with no vegetation	0.025
Same, but with some grass or weeds	0.030
Channels not maintained; weeds and some brush	0.080
Natural streams	
Clean and straight; no rifts or deep pools	0.030
Clean and winding; some pools and shoals	0.040
Clean and winding; some weeds, stones and pools	0.048
Sluggish reaches with weeds and deep pools	0.070

CULTIVATED LAND AND WATERWAYS[2]

Cover	Cover density	n
Smooth, bare soil	less than 1 inch deep	0.030
	1-2 in. deep	0.033
	2-4 in. deep	0.038
	4-6 in. deep	0.045
Corn stalks (assumes residue stays in place and is not washed away)	1 ton/acre	0.050
	2 tons/acre	0.075
	3 tons/acre	0.100
	4 tons/acre	0.130
Wheat straw (assumes residue stays in place and is not washed away)	1 ton/acre	0.060
	1.5 tons/acre	0.100
	2 tons/acre	0.150
	4 tons/acre	0.250
Grass (assumes grass is erect and as deep as flow)	Sparse	0.040
	Poor	0.050
	Fair	0.060
	Good	0.080
	Excellent	0.130
	Dense	0.200
	Very Dense	0.300
Small grain (20% to full maturity — rows with flow)	Poor, 7-in. rows	0.130
	Poor, 14-in. rows	0.130
	Good, 7-in. rows	0.300
	Good, 14-in. rows	0.200

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tillage practices, and the farmers management practices (e.g. no-till, ridge plant contour, fall plow, strip till, or up and down hill farming). The next parameter, twelve, is the practice factor. This is used in the universal soil loss equation and is dependent upon percent land slope and farming practices e.g. up and down hill farming, contour farming, or contour strip cropping (Soil Conservation Service) (Table 5). The thirteenth parameter is surface condition constant. The value is based on land use and is shown in table 2. The fourteenth parameter is the aspect, which is a single digit that indicates the direction of drainage out of a cell (figure 4). The fifteenth parameter is the major soil texture of a cell is considered. The texture can be either (1) sand, (2) silt, (3) clay, or (4) peat. The sixteenth parameter is the fertilizer level in the field. These levels are (1) no fertilization, (2) low fertilization; 50 pounds of nitrogen and 20 pounds of phosphorus per acre, (3) average fertilization; 100 pounds of nitrogen and 40 pounds of phosphorus per acre, (4) high fertilization; 200 pounds of nitrogen and 80 pounds of phosphorus per acre. The seventeenth value is the availability factor, which is the percent fertilizer left in the top half inch of soil at the time of the storm. The availability factor is based on the tillage practices performed as shown in table 6. The eighteenth parameter is

Table 5. EROSION CONTROL PRACTICE FACTOR (P)

PERCENT SLOPE	UP AND DOWN HILL FARMING 1/	CONTOUR FARMING 2/	CONTOUR STRIPCROPPING	
			ANNUAL CROPS 3/	SOD CROPS 4/
0-2	1.0	0.6	0.45	0.3
2.1-7	1.0	0.5	0.37	0.25
7.1-12	1.0	0.6	0.45	0.3
12.1-18	1.0	0.8	0.6	0.4
18.1-24	1.0	0.9	0.67	0.45

1/ Up and Down Hill Farming - use this value for:

- All straight-row farming, or
- Contour farming where slope lengths exceed the slope-length limits for effective contouring shown in Part III. E.

2/ Contour Farming - use these values for:

- Contour farming where slope lengths do not exceed the slope-length limits for effective contouring shown in Part III. E., or
- Contour stripcropping where width of strips exceeds approximate terrace intervals, or
- Terraced fields farmed parallel to the terraces.

3/ Contour Stripcropping - Annual Crops - use these values where:

- Contour strips of row crop or fallow are alternated with equal-width contour strips of close-sown annual crops such as small grain, and width of strips is approximately equal to terrace intervals.

4/ Contour Stripcropping - Sod Crops - use these values where:

- Contour strips of annual crops are alternated with equal-width contour strips of sod crops including alfalfa, and width of strips is approximately equal to terrace intervals.

Table 6. Various availability factors according to tillage practice

Tillage Practice	Availability Factor (%)
Large offset disk	40
Moldboard plow	10
Lister	20
Chisel plow	20
Disk	67
Field cultivator	70
Row cultivator	50
Anhydrous applicator	85
Rod weeder	95
Planter	85
Smooth	100

Young et al. (1985)

the feedlot point source indicator. A single digit would indicate the presence of a feedlot in the cell. If there is a feedlot, five more lines of data need to be used by a feedlot subroutine. The first line of data contains feedlot area and feedlot curve number, which is based on ground cover. The second line has acres of roofed area, acres above the feedlot, and the curve number (soil cover condition) for the acres above the feedlot. The third line contains the acres below the feedlot, the curve number (soil cover condition for the acres below). The forth line has the buffer area slope, surface condition constant (based on land use) of the buffer area, and the flow length of the buffer area. The buffer area is the area between the feedlot and the channel. The fifth line contain livestock information, such as the number of livestock, the chemical oxygen demand factor, phosphorus factor, and the nitrogen factor. These factors are based on the type of animal (table 7). The nineteenth parameter is the gully source level. If the user wants an estimate of the tons of gully erosion occurring in the cell, it may be input here. The twentieth parameter is the chemical oxygen demand (COD) factor. This factor is based on landuse as shown in table 8. The last parameter is the impoundment factor. This factor would indicate the presence of an impoundment terrace system in the cell. If there is an impoundment

Table 7. Ratio of total nitrogen produced by various animals to that produced by a 1,000-pound slaughter steer.

Animal type	Design weight (pounds)	Ratio N
Slaughter steer[1]	1,000	1.00
Young beef[1]	500	.60
Dairy cow[1]	1,400	1.68
Young dairy stock[1]	500	.46
Swine[2]	200	.26
Feeder pig[1]	50	.07
Sheep[1]	100	.13
Turkey[1]	10	.02
Chicken[1]	4	.01
Duck[1]	4	.01
Horse[1]	1,000	.81

Young etal. (1985)

Table 8. Chemical Oxygen Demand (COD) factors for various land use situations.

Land Use	COD Factor (mg/l)
Row crops	170
Small grain	80
Pasture and open	60
Alfalfa	20
Forested	65
Fallow	115
Farmsteads & Urban non-residential	80

Young et al. 1985

present, area in acres draining into the pond and the size of the outlet would need to be included in the data set.

2. Data Set Development

The information required to determine the parameters were collected from topography maps, soils maps, visual analysis and Soil Conservation Service publications. To incorporate the data collected and use it to determine the twenty-one parameters, a computer program was developed called PAULPAM3.BAS. This program is an interactive program which will help build a data base in a format that can be used by Agricultural Nonpoint Source Pollution Model I on a Hewlett Packard 1000 computer system.

3. Description of the Data Sets

The information for the AGNPS84 data set was collected in June of 1984 and was based on the practices the farmers were using in 1984. AGNPS84 stands for the model used (Agricultural Nonpoint Source Pollution Model) and the year the data was collected (e. g. AGNPS84 = 1984 data). The AGNPS84C data set had only one change, all farmers were in a no-till crop management system. The historical data sets, AGNPS00, AGNPS10,AGNPS25, AGNPS45,and AGNPS65 were a combination of two different data sets which were put together by a program called AGNPSYRS.BAS. The program uses a data set which contained all the parameters assumed to be constant over the past eighty years. These are the cell number, receiving cell number, slope shape factor, land slope, field slope length, channel slope, channel side slope, mannings roughness coefficient for the channel, soil erodibility factor, aspect, soil texture, gully source level, and impoundment factor. The other data set that changes from year to year contains Soil Conservation Service curve number, practice factor, cropping factor, surface condition constant, fertilization level, availability factor, point source indicator, and chemical oxygen demand. The primary inputs that affect the variable data set are land use, fertilization levels, tillage practices, and livestock populations. To determine the tillage practices and fertilization practices occurring in the watershed area in 1900, 1910, 1925, 1945,and 1965, a survey of 69 farmers located in and around the watershed was conducted. The survey showed that commercial fertilizer use began in 1950 and only 30 percent of the farmers were using fertilizer in 1965 (figure 6). The survey indicated that farmers did not begin to use a chisel plow until 1955 (figure 7). The data from 1980 to 1984 were affected by the Rural Clean water Program that promoted minimum tillage. To determine the historical

Figure 6. USE OF FERTILIZER AS A FUNCTION OF TIME

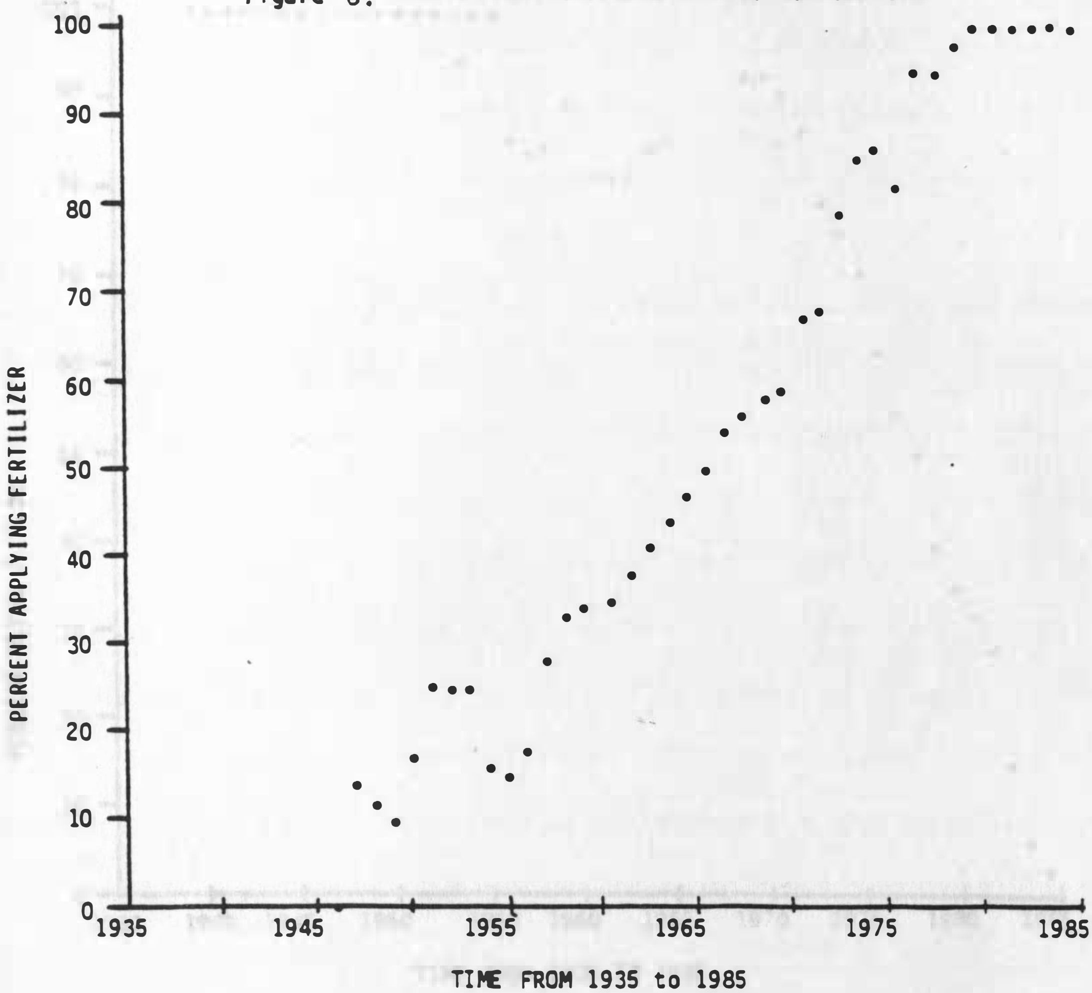
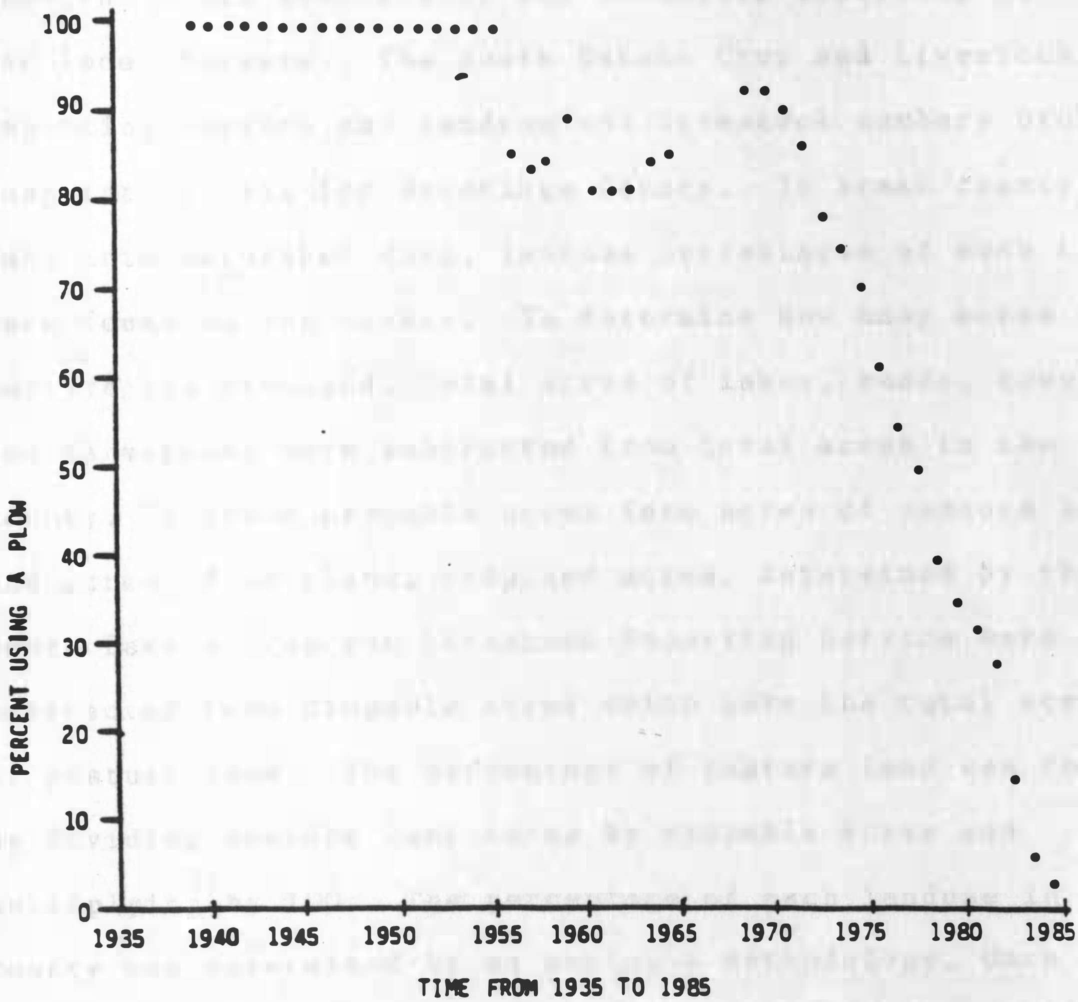


Figure 7. USE OF A PLOW AS A FUNCTION OF TIME



changes in the crops grown and livestock populations within the watershed located in Brookings County, two sources were used,the South Dakota Crop and Livestock Reporting Service and local farmers. The South Dakota Crop and Livestock Reporting Service had landuse and livestock numbers broken down into totals for Brookings County. To break county data into watershed data, landuse percentages of each crop were found in the county. To determine how many acres were pasture and cropland, total acres of lakes, roads, towns, and farmsteads were subtracted from total acres in the county. To break cropable acres into acres of pasture land and acres of cropland, cropland acres, determined by the South Dakota Crop and Livestock Reporting Service were subtracted from cropable acres which gave the total acres of pasture land. The percentage of pasture land was found by dividing pasture land acres by cropable acres and multiplying by 100. The percentage of each landuse in the county was determined by an analogus methodology. Once the percentages were found in 1900, 1910, 1925, 1945, and 1965 they were used in determining how many acres of each crop was grown in the 3675 hectare (9080 acre) watershed (table 9).

The number of livestock on any given farm was determined by taking the total amount of each animal in the county and multiplying it by the percentage of land that

Table 9. MODEL INPUT DATA - Land Use.

Land Use	Cells in 1900		Cells in 1910		Cells in 1925		Cells in 1945		Cells in 1965		Cells in 1984	
	Number*	Percent**	Number*	Percent**	Number*	Percent**	Number*	Percent**	Number*	Percent**	Number*	Percent**
Corn	13	6	18	8	63	28	74	32	70	31	84	37
Oats	20	9	25	11	68	30	62	27	37	17	40	18
Soybean	0	0	0	0	0	0	0	0	8	5	35	15
Wheat	85	37	33	15	0	0	5	3	2	1	18	8
Barley	11	5	30	13	7	3	5	3	2	1	0	0
Rye	0	0	0	0	8	3	3	1	3	1	0	0
Flax	0	0	0	0	7	3	10	5	5	2	0	0
All hay	25	11	30	13	26	11	17	8	22	10	9	4
Sorghum	0	0	0	0	0	0	2	1	1	1	0	0
Pasture	73	32	91	40	48	22	45	20	68	31	39	17
Sunflower	0	6	0	0	0	0	0	0	0	0	2	1

Cell = 40 acres
Total acres in watershed = 9080 acres

*Number of cells where corn was primary crop in that given year
Example: 1925 63 cells contained corn, etc. (or crop as listed)

**Percent land where corn (or listed crop) was grown.
Example: 1925 28% where corn was grown.

the watershed occupies in the county (88,000 cattle X 9080 acres in the watershed / 472670 acres in Brookings county = 1690 cattle in the watershed). The number of animals per farm was determined by dividing the number of animals by the number of farms in the watershed area (table 10).

To verify the data from the South Dakota Crop and Livestock Reporting Service, the results from the 1984 cropping year were compared to a windshield survey of the watershed (table 11). The Crop Reporting Service predictions for corn, oats, and wheat acres were compared to the windshield survey. The Crop Reporting Service's predictions for alfalfa, soybeans, and fallow were high compared to the survey. The predictions for oats and wheat were low due to the position of the watershed in the county. The watershed is located in the northwest corner of the county. The alfalfa prediction was high because the number of livestock presently in the watershed area is down. The other possible landuse predictions were not significantly out of proportion.

To determine historical tillage practices, fertilizer practices, landuse, and livestock numbers of each farm, a meeting was held with nine elderly farmers in the area. For the years 1900, 1910, 1925, 1945, and 1965 the farmers all presented information which agreed with information from other sources. The tillage practices

Table 10 Model Input Date--Livestock per Farm

	1900		1910		1925		1945		1965		1984	
Number of farms in Watershed	32		34		27		24		20		9	
Type Livestock	Live-stock/ farm	Farms w/animal type*	Live-stock/ farm	Farms w/animal type	Live-stock/ farm	Farms w/animal type	Live-stock/ farm	Farms w/animal type	Live-stock/ farm	Farms w/animal type	Live-stock/ farm	Farms w/animal type
Beef cattle	11	16	20	17	30	5	34	10	50	10	45	1
Beef calves	4	16	5	17	25	5	22	10	25	10	35	1
Sheep	14	16	34	17	39	6	60	12	42	10	0	0
Swine	30	16	22	17	20	21	33	11	34	10	80	1
Dairy cattle	11	16	15	17	25	22	30	13	40	10	60	6
Dairy calves	4	16	5	17	15	22	22	13	35	10	20	6

*Number of cells where beef cows (or animal listed) for that given year.
Example: in 1925 5 farms contained 30 beef cows.

Table 11. Comparison of Crop Reporting Service Predictions to the Windshield Survey

Landuse	Crop Reporting Service Landuse %	Windshield Survey Landuse %
Corn	29	37
Soybeans	16	13
Oats	7	15
Wheat	4	8
Sunflower	2	2
Flax	0	0
Rye	0	0
Millet	0	0
Alfalfa	16	4
Barley	1	0
Fallow	3	0
Pasture	16	17

in the model are those described by these farmers.

4.0 Model Calculations

The Agricultural Non-Point Source Pollution Model does its calculations in three loops. The first loop calculates upland erosion, overland runoff volume, time until overland flow becomes concentrated, level of soluble pollutants leaving the watershed via overland runoff, sediment and runoff leaving impoundment terrace systems, and contributions of pollutants due to feed lots for each cell. The second loop calculates the runoff volume leaving the cell containing impoundments and determines the sediment yield for the primary cells. A primary cell is a cell that has no other cells draining into it. The third loop routes the sediment and nutrients through the remainder of the watershed. The sediment discharge is calculated in two periods. Upland erosion is occurring and entering the channel in the first loop. In the second period upland erosion has stopped but channel flow continues.

4.1 Sediment Loss Equation

The amount of detached sediment and the break down of it into particle size classes per cell are determined by using a modified universal soil loss equation. The equation is

$$E = EI * Ks * Lf * Sf * Cf * Pf * SSF$$

E = upland erosion for a single storm in tons per acre

EI = rainfall energy-intensity in 100's of foot-ton inch per acre-hour

KS = the soil erodibility factor

Lf = the slope length factor, based on field slope length and land slope

Sf = slope steepness factor

Cf = the crop and management factor, which is derived from the crop sequence, percent ground cover, and the fall and spring tillage operations.

Pf = the practice factor, which is based on the percent slope and the type of farming practices e.g. up and down hill farming, contour farming, or contour stripcropping

SSF = slope shape factor, which adjust for a convex or concave slope

4.1.1 Sediment Routing Calculation

The sediment routing is done on a per cell per particle size bases. The equation used is

$$Qs(x) = (2*q(x)/2*q(x) + xVss) * (Qs(o) + Qsl - W* x/2 * (Vss/q(o) * (qs(o) - gs(o)) - Vss/q(x)*gs(x)))$$

Qs(x) = the particle discharge at the cell outlet in pounds per second

q(x) = the discharge per unit width existing in the cell

x = the change in channel length across the cell in feet

Vss = the lateral sediment inflow rate

W = the average channel width, which is based on side slope, peak flow rate, mannings roughness coefficient, and channel slope

qs(o) = the particle discharge per unit width into the cell

gs(o) = the particle transport capacity into the cell

gs(x) = the particle transport capacity out of the cell

4.1.2 Nutrient Loss Related to Sediment Calculation

The equation used to determine the nutrient loss related to sediment is

$$SED- = SOIL * SED * ER * 2000$$

SED- = the nitrogen and phosphorus transported by the sediment in pounds per acre.

SOIL = the nitrogen or phosphorus content in the soil, nitrogen content = .001 pounds of nitrogen per pound of soil, phosphorus content = .0005 pound of phosphorus per pound of soil

ER = the enrichment ratio, which is based on soil texture.

4.2 Runoff Calculation

The runoff volume of each cell is determined by using the Soil Conservation Curve Number method. The equation is

$$RO = (R - 0.2*S)^2/R + 0.8*S$$

RO = the runoff in inches

R = the inches of storm precipitation

S = the retention parameter, which is based on landuse, soil type, hydrologic soil condition, and storm precipitation

4.2.1 Calculation for Soluble Nitrogen Loss to Runoff

The equation used in the Agriculture Nonpoint Source Pollution Model for determining soluble nitrogen in the runoff is

$$RON = .892 * ((CZERON - CHECKN) * EXP(-XKFNI * EFI) -(CZERON - CHECKN) * EXP(-XKFN1 * EFI - EKFN2 * RO))/COEFF + RN * RP/EFRAIN$$

RON = the pound per acre of soluble nitrogen in the runoff

CZERON = the available soluble nitrogen content in the soil, which is based on the amount of soluble nitrogen in the top half inch of original soil plus the amount of applied fertilizer nitrogen left in the top half inch

CHECKN = the available nitrogen due to rainfall

XKFN1 = the rate constant for downward movement of nitrogen, which is based upon porosity

EFI = the infiltration for the storm, which is based is on the inches of rainfall, soil porosity and the amount of runoff

EKFN2 = the rate constant for nitrogen movement into the runoff

RO = the total storm runoff

COEFF = the porosity factor

RN = the nitrogen contributed by the rain.

4.2.2 Calculation for Soluble Phosphorus loss to Runoff

To Determine the amount of soluble phosphorus in the runoff an equation similiar to the nitrogen equation is used. The only difference is the phosphorus equation does not consider rainfall as a source of phosphorus. The equation used is

ROP = .892 * ((CZEROP - CHECKP) * EXP(-XKFP1 * EFI)
-(CZEROP - CHECKP) * EXP(-XKFP1 * EFI - XKFP2
* RO))/COEFF + CHECKP * RO/COEFF

ROP = the soluble phosphorus in the runoff in pounds per acre

CZEROP = the available phosphorus due to natural and commercial fertilizer

CZEROP = the concentration in parts per million of phosphorus in the pore water in the surface half inch, which is assumed to be at two parts per million

CHECKP = the soluble phosphorus in the top centimeter of soil before fertilization

EXFP1 = the rate constant for downward movement, which is based on porosity

EXFP2 = the rate constant for the movement phosphorus into the runoff; the constant relates phosphorus in the top half inch of soil

EFI = the effective infiltration, which is derived from storm rainfall, porosity, and runoff

RO = the amount of runoff

COEFF = the porosity factor

IV. Results and Discussion

The primary tillage practices, cropping practices, fertilization practices and pesticide use within the Oakwood Lakes-Poinsett watershed were obtained through a survey of the farmers in the area, Crop Reporting Service records, and other historical references. The survey was conducted person to person. The survey was performed by three technicians and myself in the summer of 1984.

1.0 The Historic Tillage Practices

Brookings County was first settled in the late 1870's. Thus the first tillage operation to occur was the plowing of sod. The moldboard plow was the primary tillage tool from 1880 to 1960. The secondary tillage tool used in the watershed consisted of a springtooth harrow and a circular disk. Tillage from 1900 to 1960 consisted of fall or spring plowing and spring disk or harrow. As disks improved farmers discontinued plowing corn stalks and started disking them in the spring. To determine the percent of farmers using a plow, a survey was conducted in the Oakwood Lakes-Poinsett area. Figure 7, percent of the farmers moldboard plowing as a function of time, was developed by taking the number of farmers using some form of primary tillage on one field other than moldboard plow (e.g. chisel plow) and dividing it by the number of farmers in the survey farming, multiplied by 100 and subtracted from 100. For example, if one farmer out of 10 used a chisel plow, the calculation would be 100 - (1 / 10 x 100) = 90 percent used a moldboard plow. Once a farmer starts to use a minimum tillage tool, our discussion indicated he continued to use it. The results show there was no minimum tillage implemented until 1956. About 20 percent of the farmers used some form of minimum tillage from 1960 to 1967, then farmers discontinued minimum tillage until 1973. From 1974 to the present, there has been a gradual decrease in the number of farmers using a moldboard plow (figure 7). The decrease in moldboard plowing is the result of the use of chisel plows, ridge-till, and other minimum tillage operations.

2.0 Historical Cropping Practices

The historical cropping practices of the Oakwood-Poinsett Lake area were taken from the crop and livestock reporting service, G.G Sandro (1936), and visual analysis. Model input data, table 9. is the percent land in a particular crop from 1900 to 1984. Brookings county was first settled in the 1870's. According to Sandro (1936), most of the farmers broke the native prairie and planted it to wheat. Sandro found farmers did not start to diversify their farm operation by planting oats, corn, and barley until 1900. Drought and increases in livestock numbers are the main reasons for diversification. As shown in table 9, in 1900, 37 percent of the land was planted to wheat. By 1910, the percent land planted to wheat dropped to 15 percent, while oats, corn, and barley showed an increase in acres planted. Land planted to corn gradually increased from 28 percent in 1925 to 37 percent in 1984. During the same time frame, land planted to oats decreased from 30 percent in 1925 to 18 percent in 1984. Soybean production in Brookings County started in the sixties and has increased every year since then. Barley, rye, flax, and sorghum have never been major crops in this area. The amount of land under hay production has decreased from 11 percent in 1925 to 4 percent in 1984. This decrease is primarily due to decrease in livestock in the area. Land planted to sunflower only occurred in 1984. The percent pasture land stayed somewhat constant over the years. The only marked change in percent was in 1965. A possible reason for the increase may have been the Soil Bank Program implemented by Soil Conservation Service through the sixties. By our criteria idle acres would have been classified as pasture.

3.0 Historical Soil Sampling

Soil Sample Testing is the best management practice for a farmer to determine his land's fertilizer needs. To determine the percent of farmers using this management practice with time, the number of farmers per year soil sampling one of their fields was divided by the number of farmers in the survey farming (figure 8). For example, if two farmers were sampling out of twenty farmers in the survey farming, the calculations would be 2/20x100, which would equal ten percent of the farmers in the survey soil sampled. Farmers did not begin sampling until 1955. In 1970, about 15 percent of the farmers soil sampled. In the next ten years the percentage of farmers sampling doubled. The large percentage values of 70 and 80 percent in 1983 and 1984 were due to the Rural Clean Water Program, which provides economic incentives to soil test. The Rural Clean Water Program was jointly implemented by Agricultural Stabilization and Conservation Service, Soil Conservation Service, and the South Dakota State University Extension Service.

4.0 Historical Fertilizer Use

The percent of the farmers using fertilizer as a function of time was determined by taking the number of farmers per year applying fertilizer one of their fields and dividing it by the number of farmers in the survey farming multiplied by one hundred (figure 6). For example, if five farmers out of twenty had used fertilizer, the calculations would be 5/20x100, which would equal 25 percent of the farmers fertilizing. Fertilizer was first used in 1946. In 1966 50 percent fertilized and in 1976 100 percent of the farmers used fertilizer at one time.

The kilograms per hectare of nitrogen and phosphorus applied to the watershed are shown in figures 9 and 10. The total tons of nitrogen and phoshorus used in Brookings county was available for several years. The data was used to extrapolate the tons used in the watershed. Until 1963 less than five kilograms per hectare of nitrogen was used. From 1964 to present there was a sharp increase in nitrogen use. The increase was from 7 to 45 kilograms per hectare. Phosphorus in the watershed was less than 5 kilograms per hectare until 1966. From 1966 to present phosphorus has increased to approximatly 20 kilograms per hectare.

5.0 Historical Pesticide Use

The percentage of farmers using pesticides (figure 11) as a function of time was determined by dividing the

Figure 9. KILOGRAMS PER HECTARE OF NITROGEN APPLIED PER YEAR IN THE WATERSHED

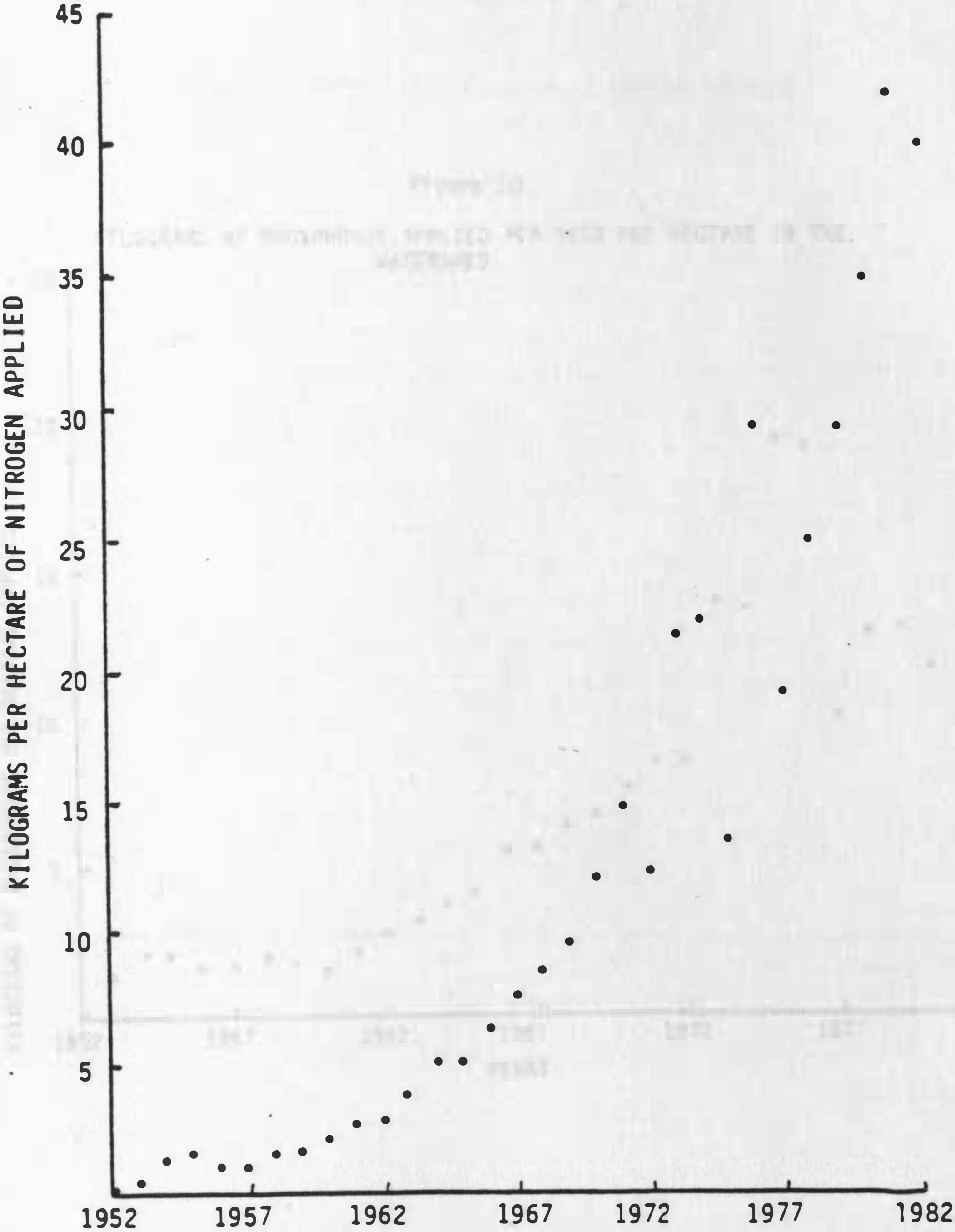


Figure 10.

KILOGRAMS OF PHOSPHORUS APPLIED PER YEAR PER HECTARE IN THE WATERSHED

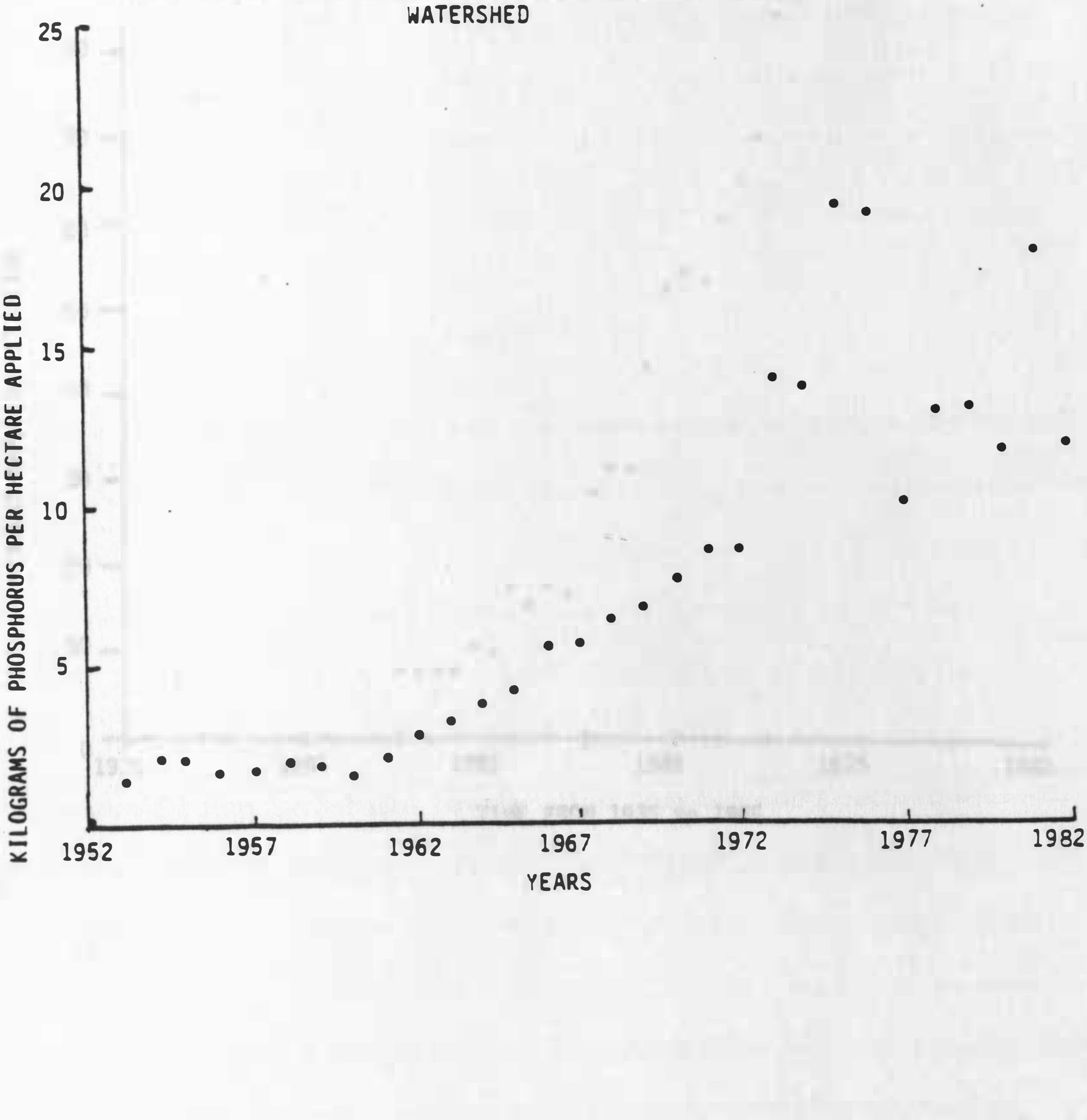
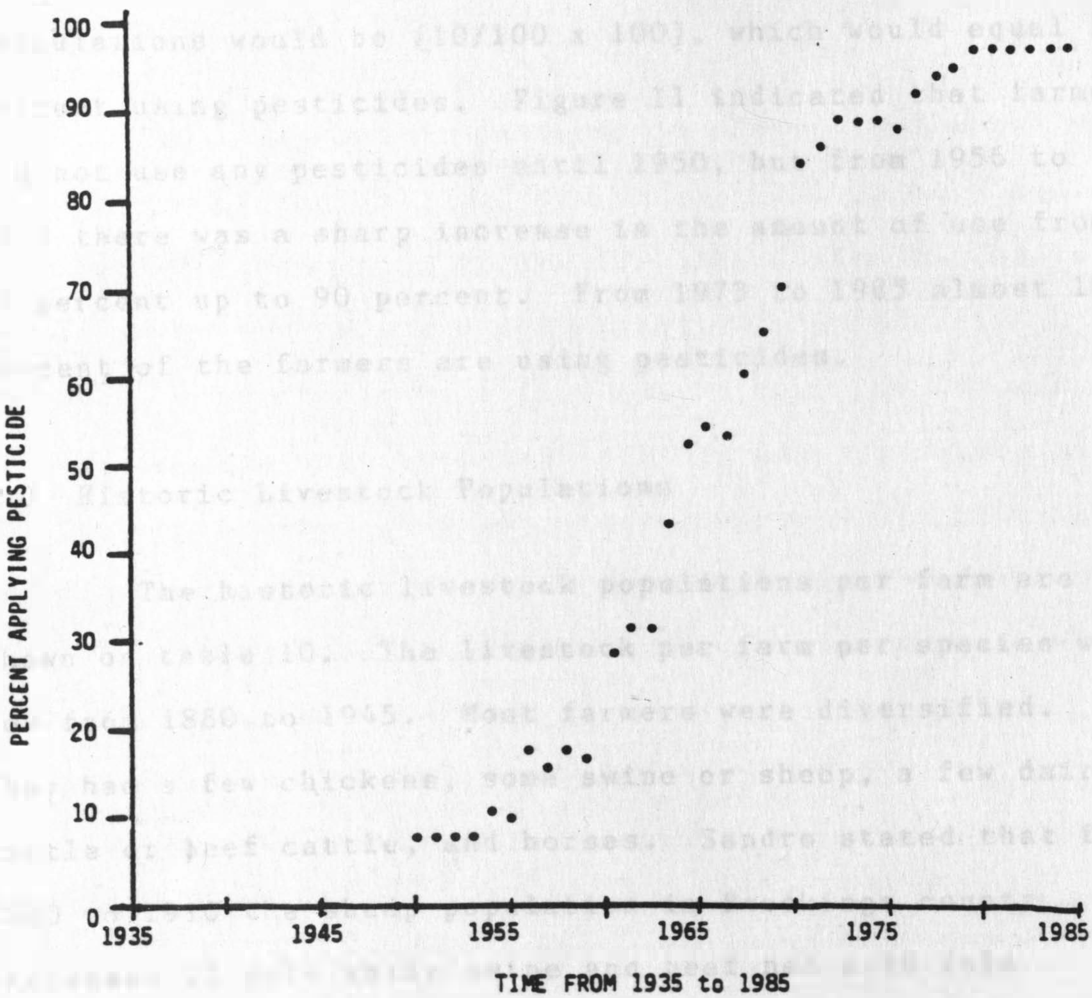


Figure 11. USE OF PESTICIDES AS A FUNCTION OF TIME



number of farmers per year using pesticides on one of their fields by the number of farmers in the survey farming. For example, if 10 out of 100 used pesticides then the calculations would be (10/100 x 100), which would equal 10 percent using pesticides. Figure 11 indicated that farmers did not use any pesticides until 1950, but from 1956 to 1973 there was a sharp increase in the amount of use from 15 percent up to 90 percent. From 1973 to 1985 almost 100 percent of the farmers are using pesticides.

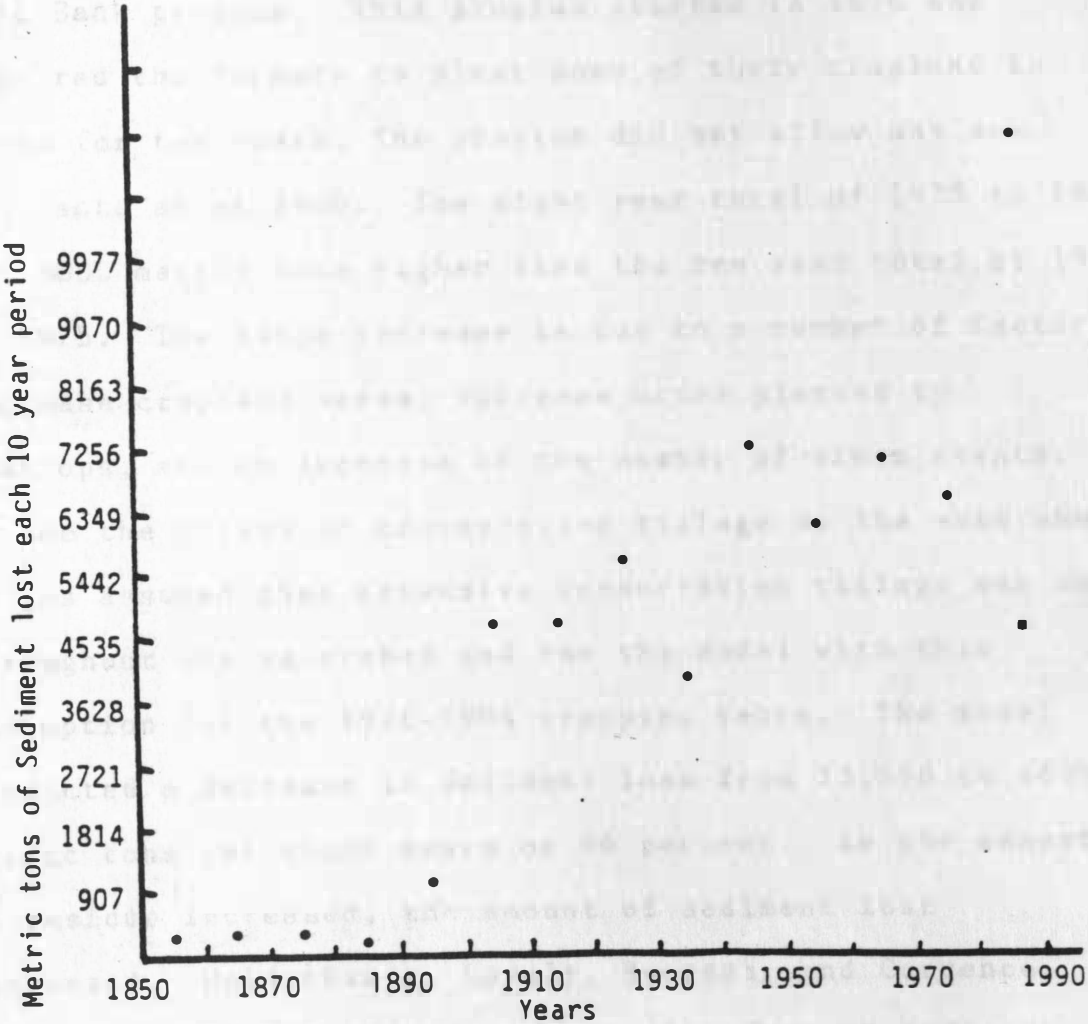
6.0 Historic Livestock Populations

The historic livestock populations per farm are shown on table 10. The livestock per farm per species were low from 1880 to 1945. Most farmers were diversified. They had a few chickens, some swine or sheep, a few dairy cattle or beef cattle, and horses. Sandro stated that from 1880 to 1910 the sheep population in Brookings county increased 22 fold while swine and beef had a 10 fold increase. From 1925 to 1965 beef populations increased steadily, while swine populations stayed constant. The sheep population decreased in the 1920's, but increased in the 1940's. From 1945 to 1984 farmers began to specialize in no more than one or two species. From 1965 to 1984 farmer discontinued sheep production and went to dairy cattle, beef cattle, or swine.

7.0 Sediment Loss to Runoff

The summation of sediment in metric tons which were carried out of the 3675 hectare watershed over each ten-year period is shown in figure 12. The sediment loss to runoff in metric tons was determined form 1850 to 1983. The model predicted that 60,120 metric tons (66,253 tons) of sediment was deposited initially in Lake Tetonkaha of the Oakwood Lakes. This is equivalent to 4.07 hectare-meter of soil (33 acre-foot). From 1850 to 1895 very little sediment made its way into the lake. The primary reason for this was the lack of farming and the existence of native prairie. People did not begin to move into Brookings county until 1870. The period between 1895 and 1925 showed a large increase in sedimentation, from 1000 to 4600 metric tons per ten year period deposited in Lake Tetonkaha. The increase was the result of native prairie being plowed under. From 1925 to 1935 there was a 1800 metric ton decrease in sedimentation, which largely resulted from a decrease in the number of storm events. There were 30 more storm events from 1915 to 1925 than from 1926 to 1935. The ten year total of 1955 to 1965 decreased

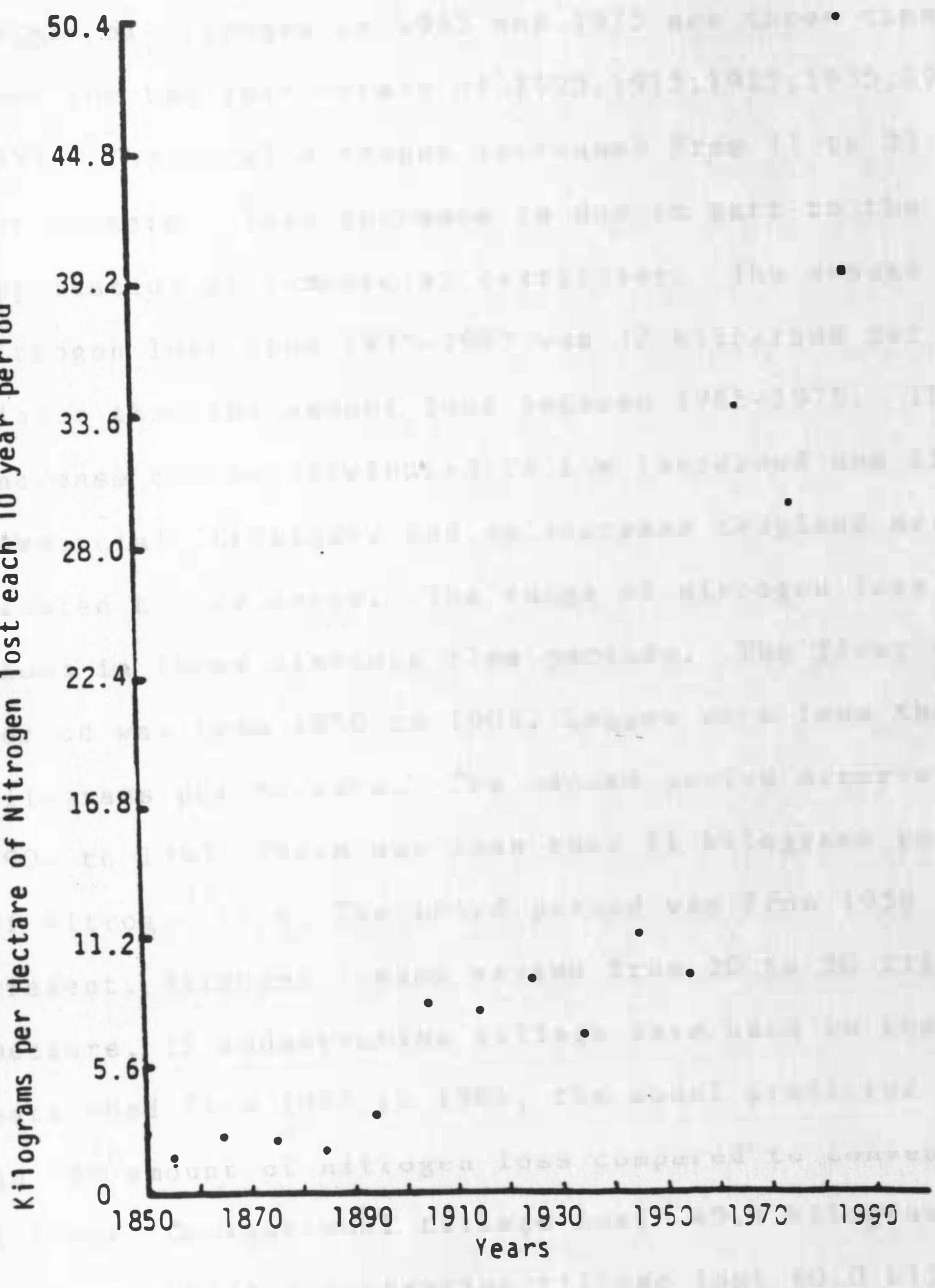
FIGURE 12. METRIC TONS OF SEDIMENT LOSS TO RUNOFF OVER EACH TEN-YEAR PERIOD.



- ● Summation of sediment in Metric tons which was carried out of 3675 hectare watershed over each ten-year period.
- ■ Metric tons of sediment lost under conservation tillage in 1984.

1000 metric tons compared to the ten year total of 1935 to 1945. The decrease is probably due to the Soil Conservation Soil Bank program. This program started in 1956 and required the farmers to plant some of their cropland to grass for ten years. The program did not allow any new contracts after 1960. The eight year total of 1975 to 1983 was 5000 metric tons higher than the ten year total of 1965 to 1975. The large increase is due to a number of factors: increase cropland acres, increase acres planted to rowcrops, and an increase in the number of storm events. To see the effect of conservation tillage on the watershed it was assumed that extensive conservation tillage was used throughout the watershed and ran the model with this assumption for the 1976-1984 cropping years. The model predicted a decrease in sediment loss from 13,676 to 4639 metric tons per eight years or 66 percent. As the amount of residue increased, the amount of sediment lost decreased. Moldenhauer, Lovely, Swanson, and Currence (1971) studied the effect percent slope has on sediment loss under conservation tillage, till-plant, and ridge tillage. They found on a 3.4 percent slope conventional tillage lost 20.1 tons per acre, till-plant lost 16.3 tons per acre, and ridge tillage lost 6.8 tons per acre. When ridge tillage was compared to conventional tillage a 66 percent reduction in sediment lost was recorded. Johnson et

FIGURE 13. KILOGRAM PER HECTARE OF NITROGEN LOSS TO RUNOFF OVER EACH TEN-YEAR PERIOD



● The summation of Nitrogen in kilograms per hectare which was carried out of the 3675 hectare water-shed over each ten-year period.

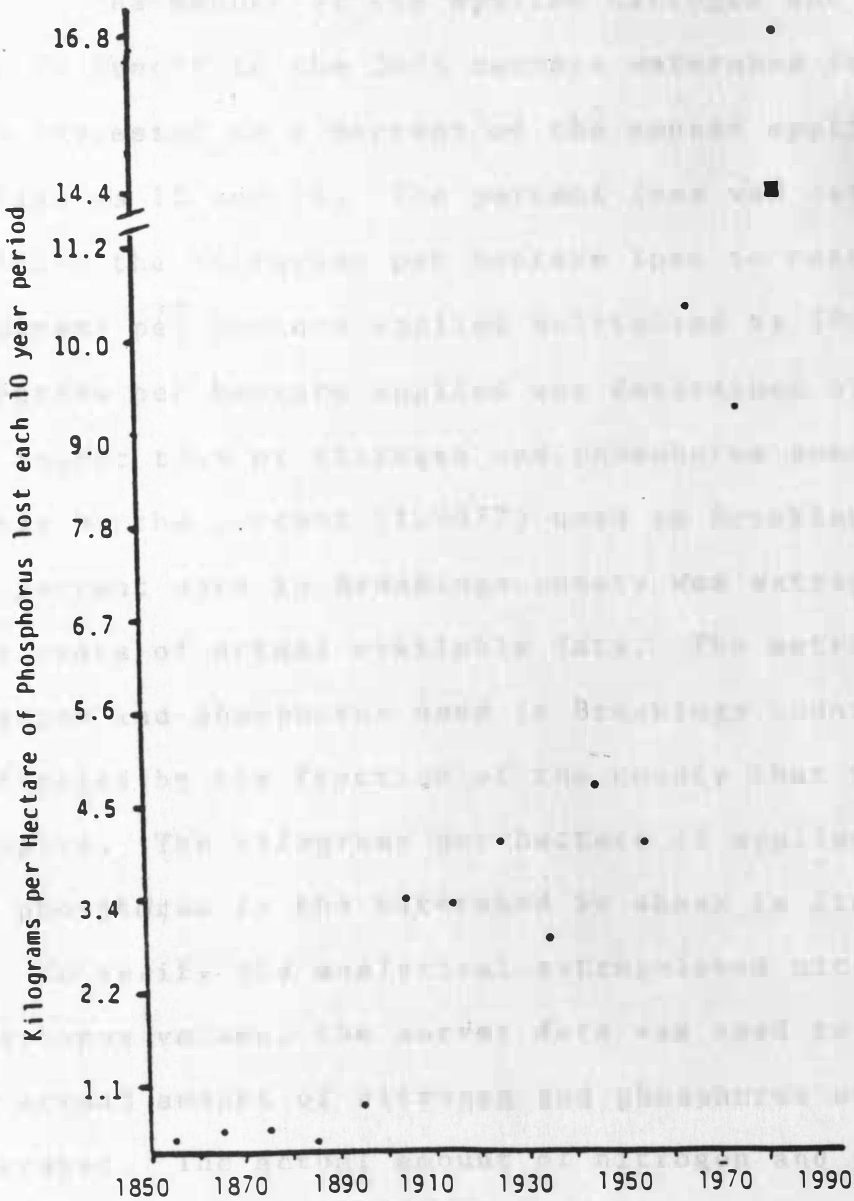
■ Kilograms per hectare of Nitrogen lost under conservation tillage.

in cropland acres. As cropland acres increased, the amount of sediment absorbed nitrogen increased. The ten year totals of nitrogen in 1965 and 1975 are three times higher than the ten year totals of 1905,1915,1925,1935,1945, and 1955. The total nitrogen increased from 11 to 33 kilograms per hectare. This increase is due in part to the application of commercial fertilizer. The amount of nitrogen lost from 1975-1983 was 22 kilograms per hectare higher than the amount lost between 1965-1975. The increase can be attributed to the increased use of commercial fertilizer and an increase cropland acres planted to row crops. The range of nitrogen loss can be shown in three distinct time periods. The first time period was from 1850 to 1905. Losses were less than 5 kilograms per hectare. The second period occurred from 1906 to 1955. There was less than 11 kilograms per hectare of nitrogen lost. The third period was from 1956 to present. Nitrogen losses varied from 30 to 50 kilograms per hectare. If conservation tillage were used in the entire watershed from 1976 to 1984, the model predicted a decrease in the amount of nitrogen loss compared to conventional tillage. Conventional tillage lost 49.9 kilograms per hectare, while conservation tillage lost 40.0 kilograms per hectare. These conclusion are in agreement with Johnson et al. 1979, Baker and Laflen 1982,and Laflen et al. 1978.

9.0 Phosphorus Loss to Runoff

The mass of phosphorus carried out of the 3675 hectare watershed over each ten year period is displayed in figure 14. The Agriculture Nonpoint Source Pollution Model predicted 60.5 kilograms per hectare (54 pounds per acre) was lost to runoff from 1850 to 1983. This amounts to 222,337 kilograms (490,138 pounds) of phosphorus entering Lake Tetonkaha. From 1850 to 1895 very little phosphorus was lost, less than one kilogram per acre each ten years. This is primarily due to the lack of erosion. From 1895 to 1955 about 4.5 kilograms of phosphorus were lost every ten years. The increase probably resulted from an increase in cropland acres, which would result in more erosion. From 1965 to 1983 there is another increase in the rate of phosphorus loss, from 9.2 to 16.8 kilograms per hectare every ten years. This increase can be attributed to the increase use of commercial fertilizer. When conservation tillage was implemented, the amount of phosphorus lost from 1976 to 1984 was 2.4 kilograms per hectare less than when conventional tillage was used. The reduction is the result of less sediment being lost to erosion. Thus, less phosphorus is lost to runoff. This is in agreement with Johnson et al. 1979, Baker and Laflen 1982, and Enzminger 1952.

FIGURE 14. KILOGRAMS PER HECTARE OF P LOSS TO RUNOFF OVER EACH TEN-YEAR PERIOD



● The summation of Phosphorus in kilograms per hectare which was carried out of the 3675 hectare watershed over each ten-year period.

■ Kilograms per hectare phosphorus lost under conservation tillage.

10.0 Percent Fertilizer Lost to Runoff.

The amount of the applied nitrogen and phosphorus lost to runoff in the 3675 hectare watershed form 1930 to 1984 expressed as a percent of the amount applied is shown in figures 15 and 16. The percent loss was determined by dividing the kilograms per hectare lost to runoff by the kilograms per hectare applied multiplied by 100. The kilograms per hectare applied was determined by multiplying the metric tons of nitrogen and phosphorus used in South Dakota by the percent (1.9877) used in Brookings county. The percent used in Brookings county was extrapolated from four years of actual available data. The metric tons of nitrogen and phosphorus used in Brookings county was multiplied by the fraction of the county that the watershed occupied. The kilograms per hectare of applied nitrogen and phosphorus in the watershed is shown in figure 9 and 10. To verify the analytical extrapolated nitrogen and phosphorus values, the survey data was used to determine the actual amount of nitrogen and phosphorus used in the watershed. The actual amount of nitrogen and phosphorus applied to corn, small grain, and soybeans was calculated and multiplied by the acres of each crop grown in the watershed in 1984. The amount of fertilizer applied was 161 tons of nitrogen and 105 tons of phosphorus. These

Figure 15. PERCENT NITROGEN APPLIED LOSS TO RUNOFF

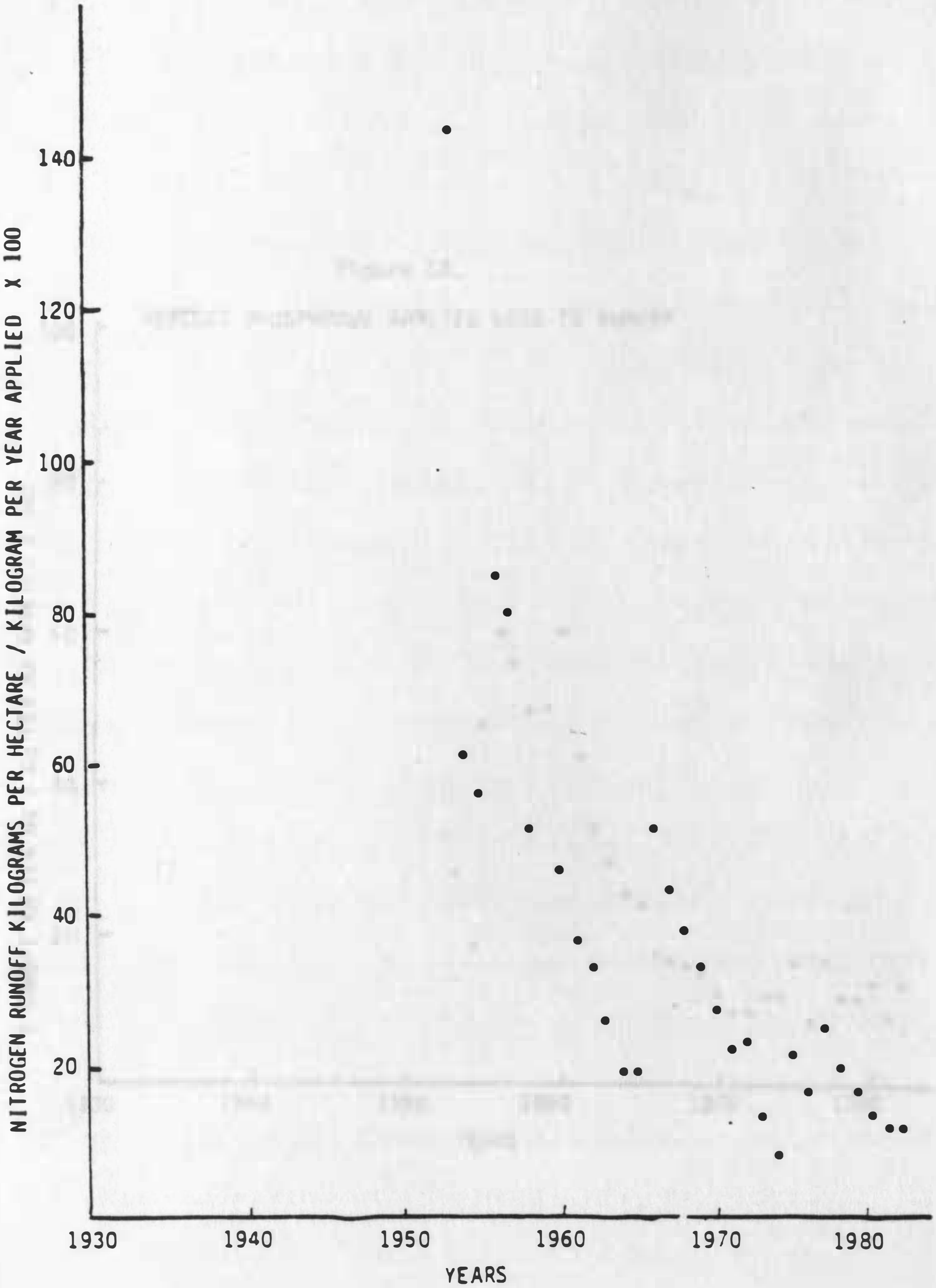
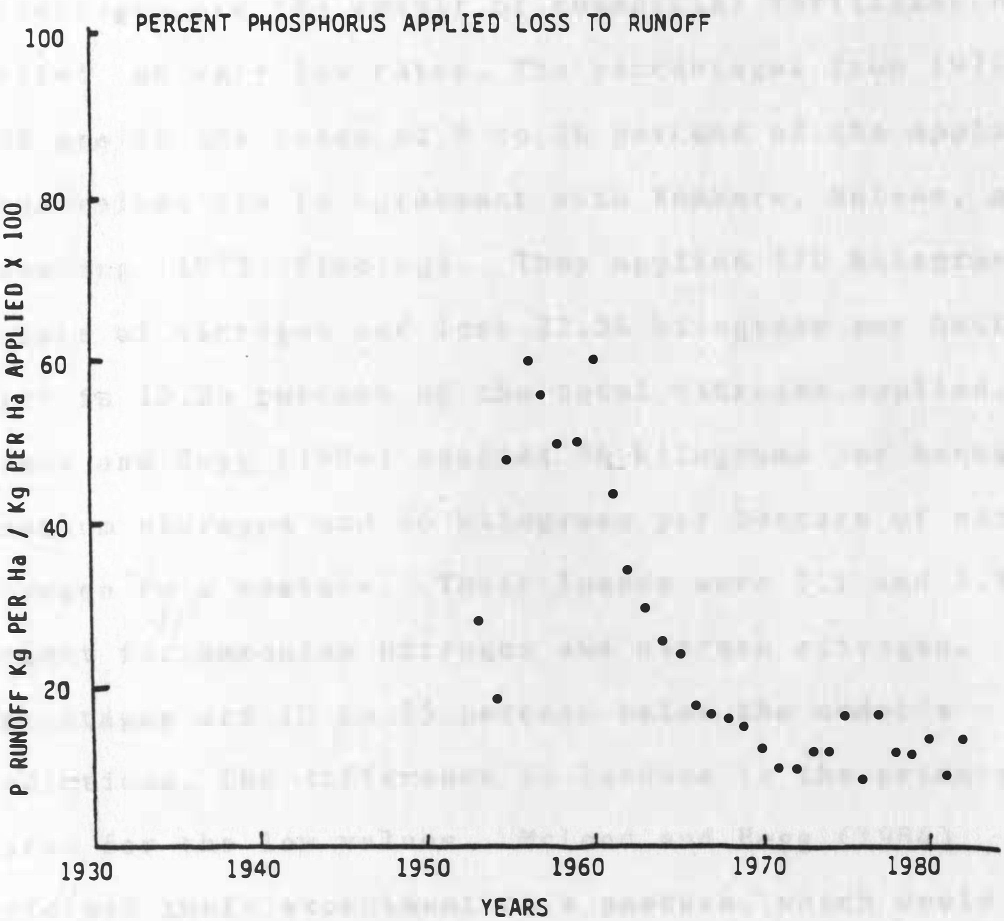


Figure 16.


PERCENT PHOSPHORUS APPLIED LOSS TO RUNOFF
P RUNOFF Kg PER Ha / Kg PER Ha APPLIED X 100
100
80
60
40
20
1930
1940
1950
1960
1970
1980
YEARS

values are comparable to the estimated tons of nitrogen and phosphorus (162 tons and 49 tons) calculated from the South Dakota Crop and Livestock Reporting Service data.

The percent of the nitrogen applied, that was lost to runoff is displayed in figure 15. From 1953 to 1970 there is a decrease from 144 to 28 percent. The high percentages are the result of commercial fertilizer being applied at very low rates. The percentages from 1971 to 1982 are in the range of 8 to 26 percent of the applied. These values are in agreement with Romkers, Nelson, and Mannering (1973) findings. They applied 170 kilograms per hectare of nitrogen and lost 22.54 kilograms per hectare, which is 13.26 percent of the total nitrogen applied. Mcleod and Hegg (1984) applied 56 kilograms per hectare of ammonium nitrogen and 56 kilograms per hectare of nitrate nitrogen to a pasture. Their losses were 7.1 and 3.9 percent for ammonium nitrogen and nitrate nitrogen. These percentages are 10 to 15 percent below the model's predictions. The difference in landuse is the primary reason for the low values. McLeod and Hegg (1984) performed their experiment on a pasture, which would cause a decrease in sediment adsorbed nitrogen lost.

The percent phosphorus applied lost to runoff is shown in figure 16. From 1953 to 1965, the percentage are inflated due to a limited amount of commercial fertilizer use. The values from 1966 to 1983 range from 9.0 to 18.0 percent with an average of 12.6 percent lost to runoff. These values are in agreement with Ensninger (1952). In his study an average of 11.5 percent of the total phosphorus applied was unaccounted for, which was assumed to be lost to runoff. Romkens, Nelson, and Mannering (1973) lost 7.0 percent of the applied phosphorus, which was primarily sediment adsorbed phosphorus.

V. Summary

The historical tillage practices, cropping practices and pesticide use within the Oakwood Lakes - Poinsett project area was derived through a person to person survey, the Crop and Livestock Reporting Service and other historical references. The Agricultural Nonpoint Source Pollution Model was used to determine the effect of historical cropping practices on the transport of sediment, nitrogen, and phosphorus through and out of a 3675 hectare watershed. The model was also used to determine the effect conservation tillage has on these same parameters.

The historical tillage of the watershed included no minimum tillage practices until 1956. From 1974 to the present there has been a gradual shift towards minimum tillage. Currently 95 percent of the farmers use some type of minimum tillage in their operation.

The historical cropping practices in the Oakwood Lake-Poinsett area were determined. Farmers planted primarily wheat until 1900. The farmers then diversified into livestock, corn and oats. In the sixties, soybean production began and has increased dramatically. Currently 15 percent of the land is planted to soybeans.

The first application of fertilizer, according to our documents was in 1947. In 1966 fifty percent of the farmers used fertilizer on some of their farmed ground. From 1976 to present, this figure increased to 99 percent. Farmers are currently fertilizing at an average rate for the entire watershed of 40 kilograms per hectare of nitrogen and 12 kilograms per hectare of phosphorus.

The use of pesticides by farmers was not documented until 1950. From 1956 to 1972, farmers using pesticide on at least one of their croped fields increased from 15 to 90 percent. Presently, one-hundred percent of the farmers use pesticides.

The Agricultural Nonpoint Source Pollution model is an event based model which works on a cell basis. There are twenty-one parameters used to characterize each cell. These parameters can be obtained via visual analysis, topography maps, soil maps, and various publications. The model uses a modified universal soil loss equation to predict upland erosion. Runoff is determined by using the Soil Conservation Curve Number Method, which is based on storm precipitation and a retention parameter. Adsorbed nitrogen and phosphorus loss is computed by the model by a constant, which quantifies the nutrient loading of the sediment moved from the field. The model determines the amount of nitrogen and phosphorus in the top one half inch of soil and uses a rate constant for the movement of the soluble forms either into the soil profile or into the runoff. Once the nitrogen and phosphorus reaches an intermittant stream or channel, it is assumed it will stay and not leach out.

The Model's predictions showed that very little sediment was lost before 1900. From 1900 to the present sediment losses have increased as acreage was converted from pasture, hayland, and small grain production to rowcrop production. The model was used to depict the hypothetical effect of 100 percent conservation tillage in the watershed. Under these conditions the model predicted a 66 percent decrease in the amount of sediment lost.

Model predictions of nitrogen loss were computied for ten year time increments and an increasing trend with time was clearly present. The predictions of nitrogen lost over time can be separated into three levels. The first level of loss occurred between 1850 and 1900 and predicted losses less than 5 kilograms per hectare per ten years. The low level of loss can be attributed to the lack of tilled soil. The intermediate level of nitrogen loss, 8 to 12 kilograms per hectare in a ten year period, was computed during the 1900 to 1965 time period. The increase in nitrogen loss originated from the conversion of pasture, hayland, and small grain production to rowcrop production. The final level which occured between 1965 and 1983 showed the largest losses of nitrogen, 50 kilograms per hectare per ten years. When conservation tillage was hypothesized, the model predicted a loss of ten kilogram per hectare per year.

The phosphorus loss predictions made by the model were computed for ten year time increments and a an increasing trend was present. Three distinct levels of phosphorus lost to runoff were seen. The phosphorus losses occurred in the same time frames as the nitrogen losses. The theoretical implementation of 100 percent conservation tillage resulted in a phosphorus savings of 2.4 kilogram per hectare per ten years.

VI. Practical Implication of Study

The increase use of fertilizer and pesticides in agriculture today has brought about a number of questions from enviromentalists and health officials. Can we determine the amount of applied fertilizer being lost to runoff? What management practices will slow down the movement of these chemicals?

The Agricultural Nonpoint Source Pollution Model has the ability to predict the amount of nutrients and sediment moving into our lakes and streams from field sources. The model looks at three things, hydrology (estimate of the amount of runoff and peak runoff rate), erosion (upland and channel erosion), and nutrient losses (nitrogen, phosphorus, and chemical oxygen demand). The Agricultural Nonpoint Source Pollution Model output can be for a single cell or for the entire watershed. The basic output of the model gives the watershed acreage and cell acreage, storm precipitation and erosivity, runoff volume and peak flow rate and a detailed analyses of sediment and nutrient yield at the outlet of cell or watershed. A detailed sediment analysis is comprised of area weighted upland and channel erosion rates, sediment enrichment ratios, mean sediment concentration and sediment yield. These values are broken down into five particle size classes (clay, silt, small aggregate, large aggregate, and sand). The detailed nutrient analysis includes soluble and adsorbed nitrogen, phosphorus, and chemical oxygen demand and the nitrogen, phosphorus, and chemical oxygen demand concentration in the runoff. The model also has the ability to calculate runoff loading from feedlots. The model output contains nitrogen, phosphorus, and chemical oxygen demand concentrations and nitrogen, phosphorus, and chemical oxygen demand at the discharge point.

The results of this investigation have shown that little nitrogen and phosphorus moved into Oakwood Lakes before 1965. The increased use of commercial fertilizer has caused a ten fold increase in nitrogen runoff and four fold increase in phosphorus runoff. Historically the loss of sediment has been a problem since the breaking of native prairie. The use of this model as an analytical tool will not only give us historical information but will give a fast and easy means of determining the effect of conservation practices before they are implemented.

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APPENDIX

Table A1.

LANDUSE CALCULATIONS

Total acres in the county:
33.5 miles X 24 miles X 640 acres per section = 514,560 acres

Acres of roads:
33.5 miles X 100 feet X 1 mile/5280 feet X 2 X 640 acres/miles squared = 19,460 acres

Acres of lakes:
24 sections X 640 acres = 15,360 acres

Acres of towns:
11 sections X 640 acres = 7,040

Acres of Farmsteads:
33 miles X 24 miles X 20 acres/section X 1 section/mile squared = 15,840 acres

Total Cropable Acres = 456,800 acres

Table A2 NITROGEN AND PHOSPHORUS APPLIED AND PERCENT LOSS TO RUNOFF IN THE WATERSHED

Year	Kg/Ha Applied Nitrogen	Kg/Ha Applied Phosphorus	Percent Loss to Runoff Nitrogen	Percent Loss to Runoff Phosphorus
1951	0.0	0.0	0	0
1952	0.0	0.0	0	0
1953	0.7	1.4	144	28
1954	1.6	2.1	85	19
1955	1.8	2.1	81	48
1956	1.2	1.7	61	60
1957	1.3	1.8	57	56
1958	1.9	2.0	52	50
1959	1.9	1.9	46	51
1960	2.1	1.7	37	60
1961	2.7	2.3	34	34
1962	2.9	2.9	26	30
1963	3.9	3.3	27	26
1964	5.2	3.9	19	26
1965	5.2	4.3	19	24
1966	6.4	5.6	52	18
1967	7.8	5.8	44	17
1968	8.8	6.4	39	16
1969	9.9	6.9	34	15
1970	12.3	7.7	28	13
1971	15.0	8.7	23	10
1972	12.4	8.7	24	10
1973	21.4	14.0	14	12
1974	24.0	13.7	8	12
1975	13.7	9.5	22	17
1976	29.6	19.2	17	9
1977	19.3	9.9	26	17
1978	25.1	13.1	20	12
1979	29.6	13.1	17	12
1980	35.3	11.7	14	14
1981	42.6	18.3	12	9
1982	40.2	12.0	12	14

Table A3. SEDIMENT, NITROGEN, AND PHOSPHORUS LOST TO RUNOFF

Ten Year Period	Metric Tons Sediment	Kg/Ha Nitrogen	Kg/Ha Phosphorus
1846-1855	244.1	1.64	0.23
1856-1865	402.4	2.42	0.34
1866-1875	354.9	2.39	0.34
1876-1885	299.2	1.85	0.23
1886-1895	1236.2	3.40	0.77
1896-1905	5835.8	8.28	3.40
1906-1915	5812.6	8.00	3.28
1916-1925	7046.6	9.32	3.97
1926-1935	4927.1	6.77	2.77
1936-1945	8859.2	11.37	4.62
1946-1955	7555.9	9.79	4.01
1956-1965	8625.1	34.48	10.48
1966-1975	8135.1	29.94	9.23
1976-1985	13676.5	49.93	16.80
1976-1985*	4639.3	40.00	14.40
TOTAL	60120.0	179.00	60.50

*Conservation Tillage